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HOW DLA'S SUPPLY PERFORMANCE AFFECTS AIR FORCE READINESS

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This report establishes a link between DLA supply performance and Air Force readiness. It does so explicitly by projecting the number of additional aircraft that could be expected to be either partially mission capable–supply (PMCS) or not mission capable–supply (NMCS) as a result of a change in DLA's funding or performance. One of the central findings is: for the demand-based items the Air Force has placed in DLA's Weapon System Support Program (WSSP), a one-time 20 percent ($50 million) reduction in DLA wholesale safety levels would – through the increased depot delay that would impose on Air Force bases – render an additional 30 to 40 aircraft NMCS or PMCS beyond the roughly 1,300 aircraft already NMCS or PMCS at any given time among the total Air Force fleet of 9,100.

Although the focus is on the Air Force, the results can be used to predict how DLA's wholesale performance is likely to affect aircraft and other "aircraft-sized" end items in all the Services. In that sense, the work answers longstanding questions about consumables and end-item readiness that are of interest to the entire DoD logistics community. The methods and results of the work also show that DLA can meet the central objectives of "secondary item weapon system management" – i.e., monitor its contribution to readiness and manage its supply operations to meet availability goals – without having to radically transform its conduct of supply operations.

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Certain changes are recommended in the way DLA operates the WSSP. The WSSP is DLA's program for paying special attention to, and in some cases giving special support to, those items the Services have identified as applicable to important end items and weapon systems. (The Air Force has placed more than 350,000 items in the program, out of the more than 1.2 million items it has registered under DLA management.) By changing the way items are grouped to compute safety levels, simplifying the treatment of item essentiality, and initiating a program to obtain point-of-use demand data, DLA has the opportunity to achieve significant savings in safety-level investment while at the same time improving weapon system support.

PREFACE

Although this report addresses how the Defense Logistic Agency's supply performance affects Air Force readiness, it also discusses the implications for weapon-system-oriented supply management at DLA. By extension, it applies to other organizations in the Department of Defense that manage consumables at the wholesale level.

The report should be of interest to supply managers and policymakers, particularly those charged with implementing "secondary item weapon system management" in their systems.

ACKNOWLEDGMENTS

This work was performed at the request of the Supply Management Division within the Executive Directorate of Supply Operations (DLA-O) at headquarters, Defense Logistics Agency (DLA). DLA's Operations Research and Economic Analysis Office (DLA-LO) oversaw the work as part of that office's ongoing support to DLA-O on topics related to secondary item weapon system management.

Obtaining the data used in this work required the help of many people, both at DLA and in the Air Force. The author would particularly like to thank Mr. Stan Naimon and Dr. Stan Orchowsky at DLA's Operations Research Office in Richmond, Virginia, for their help in assembling the wholesale-level data.

The author also thanks Lt Col Chet Matthews, Maj Steve Reynolds, Capt Jeff Bailey, and Mr. Wayne Faulkner – all with the Air Force Logistics Management Center in Montgomery, Alabama – for their help in providing retail-level, Air Force data and answering questions while the study was in progress.

The key idea of projecting aircraft effects by looking at changes in not mission capable–supply and partially mission capable–supply rates was suggested by Mr. T. J. O'Malley of LMI.

Executive Summary

HOW DLA'S SUPPLY PERFORMANCE AFFECTS AIR FORCE READINESS

Traditionally, managers in DoD's wholesale supply system for consumables – including all the supply managers at the Defense Logistics Agency (DLA), which is a wholesale-only organization – have not had to worry much about how their performance affects readiness. That does not imply that managers at DLA and elsewhere do not care about readiness or meeting customer needs. It only means that they have been generally content to look at internal measures of supply performance – e.g., wholesale supply availability rates and backorders by Supply Center – assuming that if those measures were in the "right" range, readiness would take care of itself. And, to be sure, readiness levels over the past few years have been high.

For at least three good reasons, however, supply managers at DLA should be interested in obtaining explicit measures that connect wholesale consumable performance and readiness: First, as the largest single wholesaler for consumables in DoD, DLA's involvement and level of business with the Services are too big (over $3.0 billion in sales each year) to rely on strictly internal measures of performance – hoping that those measures tell enough about readiness (they don't). Second, unless DLA learns to connect what it does to DoD's fundamental job – that of providing military forces appropriately configured, ready, and able to meet assigned missions – it will encounter increasing difficulties in defending its resource needs in the annual budgeting battles. And finally, without knowing the potential readiness effects of its management practices, DLA runs a very real risk of making inefficient use of the resources it gets. Recent Defense Management Review decisions to assign even greater supply responsibilities to DLA only increase the importance of DLA's paying more attention to final readiness effects.

In this report, we establish a link between DLA supply performance and Air Force readiness. We do so explicitly, by projecting the number of additional aircraft that could be expected to be either partially mission capable–supply or not mission

capable-supply (PMCS or NMCS) as a result of a change in DLA's funding or performance. One of our central findings is: for the demand-based items the Air Force has placed in DLA's Weapon System Support Program (WSSP), a one-time 20 percent ($50 million) reduction in DLA wholesale safety levels would – through the increased depot delay that reduction would impose on Air Force bases – ground or render PMCS an additional 30 to 40 aircraft beyond the roughly 1,300 aircraft already NMCS or PMCS at any given time among the total Air Force fleet of 9,100.

Although we focus on the Air Force, we believe our results are in the right ballpark for predicting how DLA's wholesale performance is likely to affect aircraft and other "aircraft-sized" end items in all the Services. In that sense, this work answers longstanding questions about the relation between consumables and end-item readiness that are of interest not only to DLA but to the entire DoD logistics community. The methods and results of this work also show that DLA can meet the central objectives of "secondary item weapon system management" – i.e., monitor its contribution to readiness and manage its supply operations to meet availability goals – without having to radically transform its conduct of supply operations.

We do not recommend that DLA simply reduce current WSSP safety levels as a way to save money. What we do recommend are changes in the way the Agency operates the WSSP in order to get more mileage out of its safety level investment. The WSSP is DLA's program for paying special attention to, and in some cases giving special support to, those items the Services have identified as applicable to important end items and weapon systems. (The Air Force has placed more than 350,000 items in the program, out of the more than 1.2 million items it has registered under DLA management.) By changing the way items are grouped to compute safety levels, simplifying the treatment of item essentiality, and initiating a program to obtain point-of-use demand data, DLA has the opportunity to achieve significant savings in safety-level investment while at the same time improving weapon system support. For F-16 items in the WSSP, for example, by grouping those items together when computing safety level requirements, we estimate DLA can save $20 million and at the same time reduce expected wholesale backorders for F-16 items by more than 25 percent.

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CHAPTER 1

BACKGROUND

CONSUMABLES MATTER

If we liken DoD parts, equipment, and weapon systems to ocean life, then consumables are the plankton of the logistics "food chain." Unlike their generally more expensive and complex depot-level-reparable cousins, consumables are the inexpensive, throwaway items that are almost always cheaper to procure than repair. But even though they may be cheap and expendable on an individual basis, in aggregate they play an important role in the logistics process. They are used heavily by maintenance at every level, they account for substantial annual investment in inventory, and they can have a direct effect on the readiness of weapon systems and other important end items.

In the DoD supply system, the wholesale level represents the interface between the Department and commercial suppliers and manufacturers in the economy. At the wholesale level, each national stock number (NSN) is assigned a Single Manager – either the Defense Logistics Agency (DLA), or the Army, Air Force, Navy, or Marine Corps – whose job it is to manage and procure the item for the Department. Wholesalers maintain inventory control points (ICPs), where item managers compute stockage requirements for their items, monitor use, and issue materiel release orders to satisfy requisitions and replenishment requests from retail-level supply points in the field.

DLA is the largest single wholesaler for consumables in DoD. Its four hardware Supply Centers – the Defense Industrial Supply Center (DISC) in Philadelphia, Pennsylvania; the Defense General Supply Center (DGSC) in Richmond, Virginia; the Defense Construction Supply Center (DCSC) in Columbus, Ohio; and the Defense Electronics Supply Center (DESC) in Dayton, Ohio – together manage more than 2.5 million consumable items. The total number of consumables managed at the wholesale level by the Army, Navy, Air Force, and Marines combined is less than half that number. [And the number of Service-managed consumables may become

smaller still, if supply management consolidation plans now being examined in the Defense Management Review (DMR) process are carried out.]

The sheer volume of business DLA does with the Services each year suggests the importance of consumables in the logistics system. Of the 2.5 million hardware items the Agency manages, 1.2 million are used by the Air Force, 1.6 million by the Navy, 0.7 million by the Army, and 0.3 million by the Marines.[1] In FY89, DLA's sales were more than $1.0 billion to the Air Force, $1.2 billion to the Navy, and $0.8 billion to the Army.[2] In terms of the overall value of supply system transactions, and accompanying wholesale replenishment costs, these numbers are comparable to those for reparables, where the resources-to-readiness question has been much more extensively studied.

While many DLA items are not intrinsically military in character, the Agency nevertheless manages a large number of items that apply to military systems. To ensure those items receive appropriate attention, DLA has a Weapon System Support Program (WSSP). Established in its present form in 1981, the WSSP allows the Services to identify DLA-managed items that apply to important end items and weapon systems. More than 40 percent of the 2.5 million hardware items DLA manages are in the WSSP. As of the end of January 1989, the Air Force had placed more than 350,000 items in the program, with applications to 206 major end items and weapon systems; the Navy had placed more than 445,000 items in the program, with applications to 203 major Navy systems; the Army had placed more than 250,000 items with applications to 452 major Army systems; and the Marines had placed more than 32,000 items, with applications to 248 major systems.

Again, even though one Service may have placed an item in the WSSP, other Services may also use the item. Thus, when we speak of U.S. Air Force (USAF)/WSSP items, it does not mean we are talking about items used only by the

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[1]"Used" by a Service means that the Defense Logistics Service Center (DLSC) in Battle Creek, Michigan, lists the Service as a user of the item in the Defense Integrated Data System (DIDS) catalog. A Service may use an item even if it does not appear on a stockage list at one of the Service's retail (base, station, post, etc.) supply points. Low-demand items, for example, are often not stocked at the retail level. The numbers given total more than 2.5 million because many DLA items are used by more than one Service.

[2]As is the case for all consumables in DoD, those in DLA are stock-funded, which means DLA maintains a revolving fund to pay for its purchases from suppliers. The fund is replenished by sales to retail-level supply points and customers, who pay for their purchases either with appropriated operation and maintenance (O&M) funds or with money from their Depot Maintenance Industrial Funds (DMIFs).

Air Force. Rather, we are talking about items that the Air Force requested be included in the WSSP. (Table A-1 in Appendix A profiles the different users for the 176,246 demand-based USAF/WSSP items examined in the study.)

OBJECTIVES

The objective of this work is to make the connection between DLA consumables and weapon system availability – focusing on the Air Force as a test case. The goals are to describe techniques that DLA can use to

- Set safety levels for USAF/WSSP items based on Air Force weapon system availability targets
- Balance DLA support for Air Force weapon systems with internal Air Force support (as reflected in Air Force safety levels for depot-level reparables, which the Air Force now determines using aircraft-availability-based stockage models)
- Determine which USAF/WSSP items should receive special attention and support on the basis of key indenture or critical-item relationships
- Estimate the effects on Air Force readiness if DLA's USAF/WSSP budget were to be cut.

These goals reflect the general management objectives of secondary item weapon system management (SIWSM) – an ongoing initiative in the Department of Defense aimed at changing the orientation and basis of supply system requirements and operations.[3]

Part of the purpose of this work is to demonstrate that DLA does not need to wait for detailed information and guidance from the Services to fulfill fundamental SIWSM objectives. The methods and results presented here show that DLA can today – using data already available from the Services – gauge impacts on system readiness and project the readiness effects of funding cuts. That message is important for DLA and other managers of consumables. Wholesale consumables

[3]See the concept paper on *Secondary Item Weapon System Management*, released in May 1985 by the Supply Management Policy Group (SMPG) and approved by the Secretary of Defense in June 1985. The SMPG is chaired by the Director for Supply Policy in the Office of the Assistant Secretary of Defense (Production and Logistics) [ASD(P&L)] and includes supply policy representatives from each of the Services and DLA. See also DLA's *Implementation Plan for Secondary Item Weapon System Management*, dated 31 January 1986, submitted to the ASD(P&L)

management has its own set of operating procedures, requirements methods, and system effects. Wholesale managers can and should understand their system's contribution to readiness in those terms, rather than wait for some future overhaul in the name of "secondary item weapon system management."

That does not mean the job is finished. DLA will need specific kinds of additional information, such as point-of-use demand data and better identification of first-indenture applications (both discussed further in the next chapter). Such information should be the focus of DLA's ongoing SIWSM effort. DLA's role will also expand as a result of DoD's consolidation initiatives in supply management. And, there are better, more weapon-system-oriented ways for DLA to set WSSP safety levels (described later). Nevertheless, an underlying theme of this work is that DLA does not have to radically transform its supply operations to meet fundamental SIWSM objectives. As the largest wholesale manager of consumables in DoD, DLA can – by evolution rather than revolution – incorporate weapon-system-oriented techniques into its current practices and, in so doing, show DoD the right way to proceed for wholesale consumables.

BACKORDERS ARE THE KEY

The first and key step to understanding the effect any supply system has on readiness is to look at the average number of backorders outstanding at any given time in the system. That average can be controlled with spares levels: the more spares, the smaller the average number of outstanding backorders; the fewer the spares, the greater the average number of outstanding backorders. Average backorders are important because readiness effects, such as weapon system availability, are calculated from them.

Average backorders reflect both the frequency of occurrence and the duration of backorders. They can be expressed by multiplying a demand rate times a nonfill rate (i.e., 1 – supply availability) times the average length of time a backorder lasts. For example, if the demand rate for an item is 2 per day and the nonfill rate is 30 percent, and a backorder lasts an average of 10 days, then once such a system is up and running, the average number of outstanding backorders will be:

$$2 \times 0.3 \times 10 = 6 \text{ backorders.} \qquad \text{[Eq. 1-1]}$$

Of course, the number of backorders at any particular time may be more or less than six – reflecting day-to-day statistical variations in demands, fills, and backorder durations. In inventory models, therefore, we calculate "expected backorders" (EBOs) that are expected (or mean) values in the statistical sense. EBOs reflect the average state of the system rather than any one particular state. This is just the kind of measure we normally use, of course, when the system we're trying to control is subject to external forces, which is certainly the case with DoD supply systems. Customer demand and (for the most part) supplier behavior are not affected by sparing policies. Computed EBOs, which *do* depend on spares policies, give supply managers a useful measure for projecting how their systems will behave even though they are subject to external factors they can't control.

In DoD supply policy, the terminology for requisition EBOs is "time-weighted requisitions short." Throughout, we are more interested in *unit* EBOs, or "time-weighted units short," representing the average number of unit backorders outstanding at any given time, rather than requisition backorders. We also distinguish between wholesale-level EBOs, which reflect backorders owed by wholesale to retail supply points, and retail-level EBOs, or "due-outs," which reflect backordered units owed by retail-level supply points to using customers (maintenance organizations).

Retail-level unit backorders are of more interest than requisition backorders because they are the key to understanding weapon system effects. The direct reason a fielded weapon system is down for supply is not because there is a backordered requisition at the depot but rather because a unit or component has failed or is missing from the system and *retail* supply has been unable to issue a replacement. This "hole" on the weapon system may be for a reparable component (an LRU – line replaceable unit) that is in base repair awaiting a consumable part (and base supply does not have any spares for the LRU), or it may be for a "consumable LRU" – a consumable item that applies directly to the system, rather than as a repair part for some other component. In either case, the hole exists on the weapon system because retail supply has been unable to issue the required part to either a repair shop or the flightline, whoever needs it.

To be sure, backordered requisitions at the depot are related to unit backorders in the field, a fact we have to keep track of in our analysis. (One reason retail-level due-outs occur is that the depot is sometimes late in filling retail replenishment

requisitions.) But in the end, we must be interested in the average number of LRU-type holes that exist on weapon systems if we want to calculate weapon system availability effects.[4]

To make the connection between backorders and weapon system availability, therefore, we need to compute in terms of unit backorders (which inventory models usually do anyway) and we have to find a way to focus on what is happening at the organizational, flightline level.

Our emphasis on unit backorders does not mean that requisition backorders at the wholesale level (so-called backorder "lines") are not important. They are of interest, however, only as an internally oriented measure of supply performance. They tell supply managers how they are doing from the perspective of the wholesale supply window looking out: Of all the requisitions we have received here at the depot, how many have we been able to fill and how many are backordered at the moment? Such measures are useful internally, but they tell very little from the external point of view of a customer trying to maintain a weapon system. That is so even if the wholesale performance figures are broken out by weapon system: If, for example, DLA's wholesale supply availability rate for F-16 parts is 89 percent, and 28,000 line backorders for F-16 items are outstanding, how many F-16s are down for lack of DLA parts? That question cannot be answered without more information. Providing that information is what this study is about.

Weapon-system-oriented supply management is (and should be) about supplementing the supply community's traditional, internal measures of performance with external, customer-oriented measures and habits of thought.

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[4]The connection between LRU EBOs and weapon system availability can be seen in the "product formula" definition of system availability, which expresses the system availability rate, A, as:

$$A = \prod_{i=1}^{n} \left(1 - \frac{EBO_i}{TI_i}\right),$$

where the product is taken over the "n" LRU components of the system. Each term in the product represents the probability that no member of the system fleet is waiting for component (i). EBO_i represents the number of "holes" for component (i), while TI_i represents the number of "slots" (total installed) for component (i).

For a more extensive discussion of the definitions and mathematics of system availability and EBO calculations, see the LMI report by T. J. O'Malley, *The Aircraft Availability Model: Conceptual Framework and Mathematics*, Task AF201, June 1983.

Weapon-system-oriented management is more, therefore, than simply stratifying by weapon system the old, internally oriented ways of thinking.

DLA AND THE AIR FORCE TODAY

In the next chapter, we describe how changes in DLA's supply performance would affect Air Force readiness. We do so by focusing on EBOs for DLA-managed items and corresponding weapon system effects. Before that, however, it is useful to know the baseline – where DLA stands with the Air Force today – given the Agency's current operating procedures and performance. To do that, again, we look at a particular set of outstanding backorders.

The backorders we are interested in are retail-level, high-priority due-outs to maintenance customers at Air Force bases. These are the backorders at the cutting edge between supply system operations and readiness – the ones that tell how well or poorly the supply system is performing. (They do not tell us, however, how efficiently the supply system is doing its job. That is a different issue, which we take up in Chapter 3.)

We go into some detail on DLA's current readiness role because the information is important and interesting in its own right and because it bears on the findings in the next chapter. It is also important for wholesale managers to know that the kind of retail-level information presented is available.

A due-out at an Air Force base occurs when base supply does not have a requested item. To get the item, base supply either has to wait for a serviceable item to come back from base repair (if the item is a reparable item that the base can repair) or it has to send a requisition off the base to the wholesale supplier. For the moment, we will ignore the due-outs for items in base repair and focus on the due-outs associated with off-base requisitions. Each such due-out is connected with an outstanding requisition. (If one requisition covers more than one due-out, each due-out is still connected with a requisition; it just happens to be the same requisition for several due-outs.) We can use the priority of the requisition to determine whether the due-out is an important, readiness-affecting backorder.

Following DoD Uniform Materiel Movement and Issue Priority System (UMMIPS) guidelines, the requisition associated with each due-out will fall into one of three categories: Priority Groups 1 and 2 requisitions correspond to high-priority

due-outs and Priority Group 3 applies to all other due-outs. Priority Group 1 and 2 due-outs are those that are preventing or impairing the base from performing – or being ready to perform – one or more of its assigned missions. High-priority due-outs would be those causing an aircraft or other important system to be in a not mission capable–supply (NMCS) or a partially mission capable–supply (PMCS) status. Such a due-out could be to flightline maintenance for an item that applies directly to an aircraft, or it could be to a repair shop for an item needed by a component in awaiting parts (AWP) status and for which an aircraft is waiting. High-priority due-outs could also reflect items missing from deployable War Readiness Spares Kits (WRSKs). All other due-outs would be associated with Priority Group 3 requisitions. Requests from maintenance for repair parts to repair items that will simply be returned to supply, for example, or requests to replenish maintenance bench stocks would be Priority Group 3 due-outs.

Supply officers at every retail-level installation in DoD, including supply officers at Air Force bases, get periodic reports that tell them how their outstanding due-outs stratify by priority. In the Air Force, these reports – called "Due-Out Schedule – Supplies" reports – are part of a monthly set of reports (collectively called the USAF Supply Management Report – "M32" for short) that describe base supply activity. A "Due-Out Schedule – Supplies" report tells the base supply officer how many due-outs were outstanding at the end of the month and stratifies them by priority group. It also sorts the due-outs by source of supply: AFLC (Air Force Logistics Command), DLA, GSA (General Services Administration), or LP (local purchase).

Worldwide summaries[5] of the "Due-Out Schedule – Supplies" reports for the last half of FY88 and all of FY89 show that an average of about 250,000 Priority Group 1, 2, or 3 due-outs are in place at any given time for DLA-managed items at Air Force bases worldwide. These are due-outs to the full range of base customers: weapons maintenance, communications maintenance, vehicle maintenance, other maintenance, and civil engineering. Of the total 250,000 due-outs for DLA-managed

[5]The Air Force's Standard Systems Center (SSC) at Gunter Air Force Base in Montgomery, Alabama, is the programming center for the Air Force's Standard Base Supply System. SSC produces a monthly summary of the M32 Supply Management Reports being produced at Air Force bases worldwide.

items outstanding at any given time, about 50,000 (20 percent) are classified as high-priority (Priority Groups 1 and 2). (Supporting data are provided in Appendix B.)

The "Due-Out Schedule – Supplies" reports also show how DLA-managed items compare to AFLC-managed spares when it comes to mission-limiting due-outs. Month to month, the worldwide summaries show that AFLC-managed items consistently account for two to three times as many of the outstanding high-priority due-outs as do DLA-managed items, as indicated in Figure 1-1.

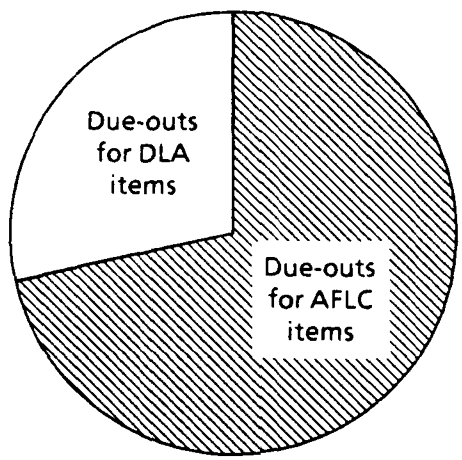


FIG. 1-1. HIGH-PRIORITY DUE-OUTS AT USAF BASES

Figure 1-1 does *not* mean that more due-outs are AFLC's "fault" or that AFLC is necessarily doing a worse or better job than DLA in providing supply support to Air Force bases. It merely tells us something about the nature of DLA-managed items compared with AFLC-managed items and the relative ability of the two sets of items to affect readiness at Air Force bases.[6]

AFLC-managed items include about 150,000 depot-level-reparable (DLR) items and about 500,000 consumable items – compared with the 350,000 USAF/WSSP items at DLA. The Systems Support Division (SSD) of the Air Force Stock Fund, operated by AFLC, is the wholesale manager for about 500,000 consumables. The

[6]In this discussion, we have focussed on due-outs associated with off-base requisitions and ignored the due-outs for items in base repair. Most of the time, the latter due-outs will be for AFLC-managed reparables, although a small number of DLA-managed parts are field-level reparables that can be repaired at the base. They, too, can generate such due-outs. Figure 1-1 does not reflect due-outs for items in repair either on the AFLC side or the DLA side. In any case, high-priority due-outs for items in base repair tend not to last very long. They are either fixed quickly, or the item is designated "not reparable this station" (NRTS) and returned to a depot and a replacement is requisitioned.

term "consumables" refers to items with Air Force expendability, recoverability, repairability category (ERRC) codes "XF3" (field-level reparable) and "XB3" (consumable). If DLA assumes responsibility for a large number of SSD items, the proportions in Figure 1-1 will change. Unfortunately, the "Due-Out Schedule – Supplies" reports do not distinguish between due-outs for AFLC-managed DLRs and due-outs for AFLC-managed SSD consumables, so we cannot predict with certainty what the new split would be. M32 "MICAP" Cause Code summaries, however, suggest that SSD items probably account for at least as many high-priority due-outs as DLA items, so a good guess would be that Figure 1-1 would change to about half-and-half if DLA takes over managing SSD items. (In Air Force terminology, a "MICAP" incident occurs when a reportable weapon system or end item enters NMC or PMC status.)

Interestingly, the "Due-Out Schedule – Supplies" reports also show that LP items account for as many (and sometimes more) high-priority due-outs as DLA items, even for weapons maintenance. Some LP items are DLA-managed, however. DLA does not carry wholesale stocks for such items, but will purchase them for overseas customers who are unable to purchase them locally.

The next step is to relate high-priority due-outs to weapon systems. We can do that by looking at NMCS and PMCS rates for aircraft. First, however, let's review what NMCS and PMCS rates are.

NMCS and PMCS rates show the percent of active aircraft – in the active Air Force, the Air National Guard (ANG), and the Air Force Reserves (AFRES) – that are not capable (or are only partially capable) of flying assigned missions as a result of lack of parts for subsystems on major command basic systems lists. What NMCS and PMCS rates actually measure are aircraft status conditions as a percent of possessed hours. If over the course of a 30-day month, for example, a 72-aircraft Tactical Air Command (TAC) wing had 3 aircraft in hangars the entire month as "cann birds" (aircraft cannibalized to provide parts for other aircraft) and 20 other aircraft on the flightline that each spent 12 hours in NMCS status at some time or other during the month, then the wing's NMCS rate for the month would be:

$$\frac{(3 \times 30) + (20 \times 0.5)}{72 \times 30} = 0.046, \text{or } 4.6 \text{ percent.} \qquad \text{[Eq. 1-2]}$$

Like average outstanding backorders, NMCS rates are "time-weighted" measures. They measure not only the occurrence of supply problems but also how long they last. If 10 aircraft had each spent 24 hours in NMCS status, rather than 20 spending 12 hours, the NMCS rate would still be 4.6 percent. As time-weighted measures, NMCS rates tell a commander what he needs to know about how his supply system is treating him: How much of the wing's resources were not available this month because supply didn't have parts?

It is important to recognize that NMCS rates – although ostensibly "supply" measures – are not determined solely by supply system actions. Rather, they reflect the end result after the *entire* logistics system – maintenance, transportation, distribution, and management – has done everything it can to maximize the number of fully mission capable (FMC) aircraft available to the commander over time. Logistics actions include cannibalization, expedited repair, expedited shipments, lateral resupply between bases, and withdrawals from WRSKs. NMCS rates, therefore, are bottom-line, real-world measures of total logistics system performance – that happen to look like supply measures.[7]

Table 1-1 shows Air Force NMCS and PMCS rates for FY89. The rates are cumulative through the end of each month. The 4.9 percent rate appearing under September, therefore, was the final, overall NMCS rate for FY89. The not mission capable-both (NMCB) and partially mission capable-both (PMCB) rates in the table reflect aircraft that were not or partially mission capable for *both* supply and maintenance at the same time.

The connection between high-priority due-outs and the rates in Table 1-1 is direct: every aircraft that spent time in either NMCS or PMCS status in FY89 did so because there was at least one high-priority due-out "owed" – either to the aircraft directly, or to a repair shop waiting for a part to fix a component needed by the aircraft.

[7]This point is important to keep in mind when seeking to "improve" supply system performance. Raising safety levels may have some effect on NMCS rates, but it is not clear whether that is cheaper or more expensive than improving some other contributing aspect of the logistics system. The costs of cannibalization, lateral resupply, and other logistics actions are notoriously difficult to quantify – unlike spares costs. We return to this point in Chapter 2 when we address the question of whether DLA supply support is in balance with internal Air Force support for Air Force weapon systems. There, in order to make fair performance-per-dollar comparisons, we use aircraft availability measures that are weapon-system-oriented, but focus exclusively on supply effects.

TABLE 1-1

FY89 NMCS/NMCB/PMCS/PMCB RATES

(Percent)

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NMCS	4.3	4.5	4.6	4.3	4.6	4.4	4.7	4.3	4.2	4.6	4.8	4.9
NMCB	5.1	5.2	4.8	5.0	5.2	5.6	5.4	5.5	5.5	5.2	5.3	5.1
PMCS	4.1	3.6	3.9	3.9	3.6	3.8	3.6	4.0	4.2	4.3	4.1	4.8
PMCB	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.8
Total	14.1	14.0	13.9	13.8	14.0	14.4	14.3	14.4	14.6	14.8	14.9	15.6

Source: "Aircraft Mission Capability Rates – Total Aircraft Worldwide," *AFLC Command Information Digest – 1st Quarter FY90.*

Note: NMCB = not mission capable – both; PMCB = partially mission capable – both.

The precise formula for connecting these rates and the high-priority due-outs discussed earlier (for both DLA-managed items and others) is complicated, of course, because it has to do with the way holes are distributed among aircraft. Also, not every high-priority is necessarily a hole on an aircraft. (High-priority holes can and do occur on systems other than aircraft.) What we can say, however, without trying to be any more precise, is that corresponding to the roughly 50,000 high-priority due-outs for DLA-managed items at Air Force bases, and the 100,000 to 150,000 high-priority due-outs for AFLC-managed items and some LP and GSA due-outs, the equivalent of about 1,300 aircraft are in either NMCS or PMCS status all the time in the total Air Force fleet of 9,100 aircraft (active, ANG, and AFRES). The number 1,300 is obtained by multiplying a combined (NMCS + NMCB + PMCS + PMCB) rate of slightly more than 14 percent times the fleet size of 9,100.

What makes the correspondence just described important is that we can use it, within a reasonable range, to predict how many more aircraft would enter NMCS or PMCS status if there were an increase in the number of high-priority due-outs at bases. For example, suppose the number of high-priority, aircraft-related due-outs for DLA-managed items at Air Force bases worldwide increased by 9.7 percent – attributable, say, to a change in DLA's wholesale supply performance. Then, because DLA items account for about one-fourth to one-third of the total number of

high-priority due-outs, we can estimate that the number of NMCS or PMCS aircraft will increase by about one-fourth to one-third of 9.7 percent of 1,300, or 32 to 42 aircraft. ($0.25 \times 1{,}300$ aircraft $\times\ 0.097 = 31.5$ aircraft; $0.33 \times 1{,}300$ aircraft $\times\ 0.097 = 41.6$ aircraft.) This is precisely the method used to obtain the "rule-of-thumb" NMCS and PMCS results given in the next chapter.

CHAPTER 2

FINDINGS

How sensitive is Air Force readiness to changes in DLA's supply performance? In the previous chapter, we looked at Air Force readiness given DLA's current performance. Here, we want to see what happens if DLA's performance changes.

GROUND RULES

The ground rules are simple: Holding the Air Force's retail stockage levels constant, we want to see what happens if wholesale stockage levels change at DLA. Wholesale levels are the only ones DLA controls, so even though the Air Force's retail systems might eventually try to react, we will hold them constant for purposes of the analysis.

In an inventory system, the term "stockage level" refers to the minimum quantity that is to be on hand or on order at any given time. In general, the stockage level for an item will be the sum of a "pipeline" (a recurring demand rate times a leadtime) and a "safety level" (to cover statistical variation about the pipeline mean). The theory is that if enough spares are in the system to cover demands while a unit waits for replenishment or resupply plus some statistical variation, then outstanding backorders can be held to an "acceptable" level.

At wholesale, the stockage level is the sum of demand in a leadtime (the average number of demands occurring over the average time it takes to get replenishment from commercial suppliers) plus a safety level. An item manager controls the performance of an item, in theory at least, by reordering it every time on-hand plus on-order (minus any backorders) reaches or falls below the authorized stockage level (also called the reorder point). At retail, the stockage level is the sum of demand in an order-and-ship time (the average number of demands occurring over the average time it takes to order and receive the item from wholesale) plus a retail safety level. Stockage levels also occasionally include "special" levels in addition to pipeline and safety levels – e.g., "protectable" war reserve requirements at the wholesale level for some DLA items.

The other ingredient in an inventory system is the order quantity. Running an inventory system basically consists of deciding when to reorder (determined by the stockage level) and how much to order (the order quantity) when that happens. For consumable items, order quantities are generally "economic" order quantities (hence the term "EOQ") designed to minimize ordering and holding costs.

The sum of the order quantity plus the stockage level for an item is often called the requisitioning objective (RO). For EOQ items, the RO represents the maximum quantity that is to be on hand or on order at any given time in the system. (Thus, for EOQ items, the sum of on-hand plus on-order will always fall between the reorder point and the RO.) Consumables have reorder points and order quantities at both echelons – wholesale and retail. DLA managers control reorder points and order quantities at the wholesale level; Air Force managers control them at the retail level. [Air Force supply policy is set by the Supply Policy Branch of the Air Staff. The Air Force Logistics Management Center (AFLMC) provides analytic support for base supply policy. AFLC runs the retail-level "D033" system for supply support to depot-level maintenance at the five Air Logistics Centers (ALCs) it operates.]

We want to see what happens if DLA changes its wholesale stockage levels. We do not analyze what happens if DLA changes its wholesale order quantities – even though that is what DLA managers will usually do (and what they should do) if faced with temporary funding shortages. In the short term, cutting order quantities can improve cash flow – often with no perceptible effect on supply performance – but it saves nothing in the long term. If customer demand holds up (which we have to assume it will), smaller order quantities simply mean more frequent buys.[1]

We look at a change in wholesale stockage levels with the idea of making an overall, uniform change – raising or lowering the safety levels for every item in the system by the same percentage – rather than changing the mix of safety levels for the same total investment. Changing the mix (which we discuss in Chapter 3) has to

[1]See Christopher H. Hanks, *Influence of Systems Support Division Funding and Safety Levels on Aircraft Availability*, LMI Report AF501-1, October 1985, for a discussion of the effects of reducing order quantities in a wholesale supply system for consumables. Generally, those effects are smaller than the effects of reducing safety levels, which is why cutting order quantities is the right thing to do in the face of temporary funding shortages. Trying to manage a permanent funding reduction with reduced order quantities does not work, however. Eventually a point is reached at which insufficient money is available to make the next (albeit smaller) buy. If the buy is not made, the reorder point is de facto lowered. At that point, the savings required by a funding reduction – perhaps postponed by the mechanism of smaller buys – are finally forced on the system in the form of lower stockage levels.

do with improving efficiency for the same level of investment; here we want to see what happens if the overall investment itself changes.

Funding cuts are the most likely reason that DLA would change (lower) its wholesale levels. The only way to guarantee savings in a supply system is to reduce stockage levels. Generally, that means lowering safety levels. Smaller safety levels mean not replacing stock that otherwise would have been replaced, which represents a real savings. Of course, smaller safety levels affect supply performance. But if DLA is asked to operate with less and cannot find more efficient ways to operate (see Chapter 3), it has no other choice.

AN AIRCRAFT-PER-DOLLARS RULE OF THUMB

As a rule of thumb, every $10 million reduction in wholesale safety levels at DLA for demand-based WSSP/USAF items has the potential to ground or render PMC 6 to 8 aircraft in the Air Force:

- 0.4 – 0.5 aircraft as a result of AWP-induced slowdowns in base and depot repair lines
- 5.6 – 7.5 aircraft as a result of increases in due-outs to the flightline for "consumable LRUs."

Demand-based items are items in the DLA Standard Automated Materiel Management System (SAMMS) whose stockage levels are calculated on the basis of historical demand patterns. In SAMMS parlance, they are Item Category Code 1 (ICC = 1) items. We are interested in demand-based items because they account for virtually all the demand and backorder activity that DLA experiences. As of March 1989, 176,246 demand-based items (the data base for the study) and 188,000 non-demand-based items constituted the total USAF/WSSP items. Non-demand-based items are numeric stockage objective (NSO) items and insurance items. Overall, the 188,000 non-demand-based WSSP/USAF items accounted for less than 0.4 percent of outstanding wholesale unit backorders and only 1.0 percent of total, annual, wholesale-level unit demand.

The rule of thumb holds even though many USAF/WSSP items are used by other Services besides the Air Force. (As can be seen from Table A-1 in Appendix A, at least one other Service uses about 75 percent of the items in the study and multiple-user items account for more than 95 percent of total annual unit demand in the USAF/WSSP program.) Our analysis was structured, however, so that the only

thing that mattered about DLA's wholesale supply performance was the percentage change in wholesale EBOs. That percentage change translates into an increase in average depot delay imposed by DLA on all its customers – Air Force and non-Air Force alike. Using retail-level models and retail data from the Air Force, we examined the effect that the increase in wholesale delay has on retail supply operations at Air Force bases, following it through to see its ultimate effect on maintenance and aircraft readiness. The same effects could be expected to hold at Army posts and Navy air stations to the extent that their retail operations and stockage levels are comparable with those of the Air Force.

The-6-to-8-aircraft-per-$10-million rule of thumb is reliable up to a $50 million change (reduction or increase) in WSSP/USAF safety levels – corresponding to a loss or gain of 30 to 40 aircraft from an available fleet of about 7,800 aircraft.[2] Such a change in safety level investment would represent

- 20 percent of the roughly $250 million DLA has invested in safety levels for demand-based WSSP/USAF items
- About 5 percent of the $1.0+ billion DLA has invested in total stockage level (pipeline plus safety level) for demand-based WSSP/USAF items.

The rule of thumb, in fact, can be applied up to a $100 million change in WSSP/USAF safety levels. Our analysis used $50 million, and linear extension of the rule above $50 million is reasonable. A $100 million change would correspond to a loss or gain of 60 to 80 aircraft out of the available fleet of 7,800. The $50 million figure corresponds to a uniform 20 percent change in wholesale safety levels for the 176,246 demand-based WSSP/USAF items in the study.

A natural objection here would be that the last thing DLA will do if faced with funding cuts will be to reduce support for demand-based WSSP items. That is true. One reason DLA has a Weapon System Support Program is to know which items to protect if funding becomes tight. However, since our objective is to determine the sensitivity of Air Force readiness to DLA actions, we must look at the DLA items most likely to influence Air Force readiness – the set of demand-based WSSP/USAF items. We chose a change of 20 percent in wholesale safety levels as a reasonable

[2]The total fleet in the Air Force in FY90 was about 9,100 aircraft. Through March 1989, the combined NMCS + NMCB + PMCS + PMCB rate was 14.4 percent (see Table 1-1). Thus, the available (i.e., not-waiting-on-supply) fleet was 9,100 aircraft minus (0.144 × 9,100) aircraft, or about 7,800 aircraft at any given time.

"delta" for the study because it is feasible and in line with the kinds of changes DoD programs are likely to face in the coming years.

An important aspect of the rule of thumb is that the aircraft-per-dollars ratio for consumable LRUs is more than 10 times that for consumable repair parts – indicating the increased potential for "leverage" that consumables have when they apply as LRUs. When used as repair parts for other components, consumables are not as influential because the system is usually able to provide spares for the items being repaired. Such "higher indenture" spares serve to buffer aircraft from consumable-item effects.

What the rule of thumb tells us is how much buffering actually goes on. The calculations were done with the Aircraft Availability Model (AAM).[3] That model was developed by LMI for the Air Force and is now being used by AFLC to compute safety-level requirements for reparables within the Air Force's "D041" Recoverable Consumption Item Requirements System. The AAM runs on a D041 data base, which includes asset information, failure rates, depot and base repair times, NRTS (not reparable this station) rates, and other item information for reparables. The D041 data used in the study are from a March 1989 D041 data base contemporary with the March 1989 DLA data in the study. In effect, the AAM allowed us to extract information from a D041 file on the extent to which the availability of spare reparables in the Air Force buffers aircraft from consumable-item effects.

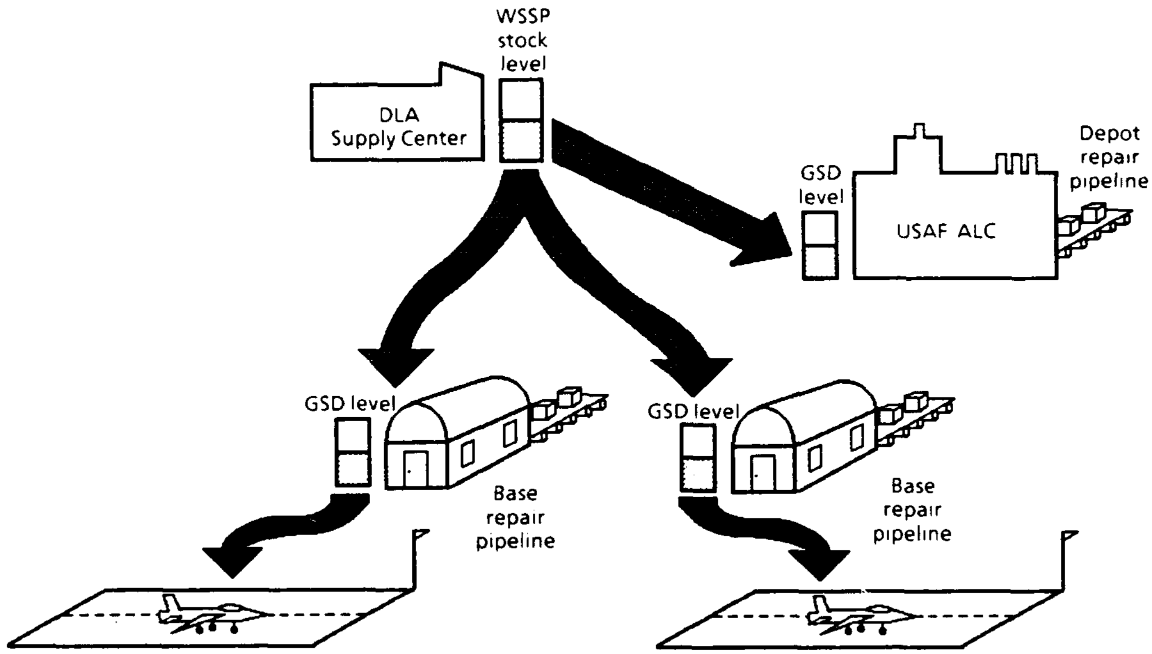
The repair effects in the rule of thumb were derived by extending base and depot repair times in the AAM and calculating the effects on aircraft availability, given no change in the Air Force's total level of investment in reparable spares.

Changes in DLA's wholesale supply performance affect base and depot repair times by causing increases or decreases in the average time that maintenance customers spend waiting at their local, retail-level supply points. When their orders are filled, customers don't wait. When base supply "issues" them a due-out, however, they do wait. Average waiting times represent the average of these zero and nonzero waiting times. If the average number of outstanding wholesale backorders for DLA items increases, base supply points must wait a little longer on average for replenishment. If retail stockage levels don't change, retail-level due-outs to

[3]The AAM is documented in *The Aircraft Availability Model: Conceptual Framework and Mathematics*, T. J. O'Malley, LMI Report AF201, June 1983.

maintenance customers will increase and repair activities will have to wait a little longer on average for the parts they need from base supply.

The various connections between wholesale DLA supply and the retail-level Air Force are summarized in Figure 2-1.



Note: GSD = General Support Division.

FIG. 2-1. THE ROLE OF WSSP/USAF PARTS IN THE LOGISTICS ENVIRONMENT

The General Support Division (GSD) stockage levels in the figure represent the retail stockage levels for DLA-managed items that the Air Force carries at its bases and maintenance depots. The GSD is part of the Air Force Stock Fund. It controls retail-level stockage in the Air Force for all the items that the Air Force itself does not manage but has to buy from other wholesalers. When a base supply point needs to replenish its stock for a DLA-managed item, it cuts a requisition and sends it to the appropriate DLA inventory control point (ICP) (one of DLA's Supply Centers). The Air Force pays for its order by citing GSD funds in the Air Force Stock Fund for payment to the DLA Stock Fund.

As Figure 2-1 suggests, DLA wholesale supply levels and performance affect retail supply performance at bases and depots for DLA-managed items. In turn, aircraft can be affected – either indirectly by changes in depot and base repair times,

or directly, when the DLA items apply directly to aircraft as consumable LRUs. The rule of thumb quantifies the final effects on aircraft readiness in both cases.

HIGH-PRIORITY DUE- OUTS

There is another way we can describe how DLA performance affects Air Force readiness. Rather than looking at aircraft effects, we can ask how the average number of outstanding high-priority due-outs for DLA items might change at a typical Air Force base. This approach puts us on ground that may be more familiar to support personnel in the Air Force, many of whom spend a significant amount of their time trying to solve problems directly related to high-priority due-outs.

The due-outs we are interested in are ones that are preventing or limiting the base from being able to perform its assigned missions. One way a consumable item can do that is if it applies directly to an aircraft and fails. If base supply does not have a replacement for that "consumable LRU," the waiting aircraft will be PMCS or NMCS until the due-out is filled.

However, we are also interested in high-priority due-outs for items that apply as repair parts for other components rather than directly to the aircraft itself. If an airplane (or other important end item) is waiting for a reparable-type item to be repaired, and the reparable itself is awaiting a part, then the due-out for the part qualifies as high priority because it is the reason the aircraft/end item is waiting.[4]

With that background, DLA's influence on Air Force readiness can be described as follows: A $50 million reduction in WSSP/USAF safety levels (corresponding to a uniform, across-the-board 20 percent reduction in the safety level for every demand-based WSSP/USAF item) would increase the number of outstanding high-priority due-outs for DLA-managed items at Air Force bases by 2,000 to 4,000 due-outs worldwide. That number includes both high-priority due-outs to flightline (organizational-level) maintenance for consumable LRUs and high-priority due-outs to back shops (intermediate-level maintenance) for consumable repair parts needed

[4]Of course, the only way an aircraft can be waiting is if base supply does not have any serviceable spares of the reparable to issue. In that case, the base may or may not have an outstanding high-priority requisition for the reparable in addition to the one for the repair part, depending on whether the base is at or below its RO for the reparable. Whichever requisition gets filled first should cause the remaining requisition to be downgraded in priority once the "hole" on the end item is filled.

by other components. This finding is based on a set of computed increases for 10 representative bases, as shown in Table 2-1.

TABLE 2-1

HIGH-PRIORITY DUE-OUTS FOR DLA-MANAGED CONSUMABLES

CONUS	Δ due-outs	Baseline	OCONUS	Δ due-outs	Baseline
Langley (1st TFW – F-15)	61	389	Clark (3rd TFW – F-4)	51	1,115
England (23rd TFW – A-10)	4	15	Bitburg (36th TFW – F-15)	6	109
Little Rock (314th TAW – C-130)	59	325	Bentwaters (81st TFW – A-10/F-16)	17	378
Minot (5th BW – B-52/KC-135)	27	156	Kunsan (8th TFW – F-16)	13	304
Randolph (12th FTW – T-37/T-38)	10	37	Elmendorf (AAC – TAC/MAC)	13	253

The 10 bases in Table 2-1 are representative of the 141 major installations (Air Force Bases, Air Reserve Bases, and Air Guard Bases) the Air Force has in the United States and around the world (as of May 1989). (The bases are 10 of the 12 bases that the AFLMC uses as a representative sample to study base-level stockage.) The "OCONUS" bases are outside the contiguous 48 states. Below each base is the name and aircraft type of the main Air Force flying unit (wing) stationed at the base. Various tactical fighter wings (TFWs), a strategic bomb wing (BW), a tactical airlift wing (TAW), and a flying training wing (FTW) are represented. A wing consists of one to five squadrons (three- and two-squadron wings are the most common), with 8 to 24 aircraft per squadron, depending on aircraft type and mission.

Each baseline figure in Table 2-1 is the average value for the number of high-priority due-outs for DLA-managed items outstanding at any given time to maintenance organizations at the base. The "delta" figures show the number of additional due-outs that could be expected if DLA were to reduce wholesale safety levels for demand-based WSSP/USAF items by $50 million. The same kinds of

increases would occur at other, similar bases in the Air Force, leading to the estimate of a total increase of 2,000 to 4,000 due-outs worldwide.

Do the baseline values in Table 2-1 track with the real world? Averaging the 10 baseline figures in Table 2-1 yields the estimate that an average base will have slightly over 300 high-priority due-outs in place for DLA items at any given time.[5] That number compares favorably to data from Air Force supply summaries (M32 reports – see the last section in Chapter 1). Those reports show that worldwide the average number of outstanding, high-priority due-outs for DLA items is about 50,000, which, with 141 major-installation-size bases in the Air Force, corresponds to an average of about 350 per base.

For an additional comparison and to verify that the number of such due-outs can vary greatly from base to base, the number of firm, high-priority due-outs for DLA items at Langley AFB at the end of October 1989 was 1,445, and at Myrtle Beach AFB (an A-10 base) it was 549. At the end of November 1989, Langley had 1,519 high-priority due-outs in place for DLA items and Myrtle Beach had 468.

A very important point is that the due-outs shown in Table 2-1 correspond not just to holes on airplanes (or holes on components that airplanes are waiting for) but to holes on other end items (and their components) as well. In fact, the due-outs in Table 2-1 relate to the more than 200 Air Force end items and weapon systems that DLA supports in the WSSP, of which only about 30 are aircraft. The others are systems such as aerospace ground equipment, radars, communication systems, air traffic control systems, missiles, and fire trucks. (Table A-11 in Appendix A lists all the Air Force systems represented in the WSSP.) *Even if they are not aircraft-related, however, all due-outs in Table 2-1 are high-priority due-outs.* That means that regardless of where each hole happens to be, and whether it's related to an aircraft or

[5]In Air Force terminology, the due-outs in Table 2-1 are for ERRC Code XB3 items, purchased through GSD under Budget Code 9. Due-outs for DLA-managed, ERRC Code XF3 (field-level-reparable) items are not included in Table 2-1 because there were no DLA-managed XF3 items in the retail-level data bases used in computing these results. Most high-priority due-outs for DLA items are still reflected, however, because although DLA does manage some XF3 items for the Air Force, most XF3 parts (70 to 80 percent according to AFLMC analyses) are managed by the Air Force itself (SSD – Budget Code 1). In any case, the total number of XF3 consumable items at a base is small compared to the number of XB3 consumables. Minot AFB, for example, had 24,569 DLA-managed XB3 items on its stockage list in March 1989, 16,467 of which were used in this study. The total number of XF3 items at Minot in 1989 was 2,528, with 1,695 (67 percent) managed by SSD, 398 (15 percent) managed by DLA, and 455 (18 percent) either local purchase items or items managed by another wholesaler.

not, the corresponding due-out is preventing or impairing the base from being able to perform its assigned missions.

A lesson here is that as a wholesale manager of consumables for the Air Force, DLA cannot and should not worry only about aircraft effects. DLA has to worry about its effect on Air Force operations overall. In that sense, the use of the term "weapon" in DLA's program to achieve "secondary item weapon system management" is unfortunate. A better name would be "secondary item *customer-oriented* management," to suggest DLA's responsibility to support *all* the end items that customers have designated as important – whether or not they are weapon systems.

What is the connection between the NMCS/PMCS aircraft effects in the rule of thumb earlier and the due-outs shown in Table 2-1? The rule of thumb reflects the effects of an increase in due-outs for DLA-managed items that necessarily have applications to aircraft. Table 2-1 shows due-outs affecting many different kinds of end items and systems – aircraft and nonaircraft alike. Table 2-2 shows what Table 2-1 looks like if we limit it to due-outs for DLA-managed items that have applications to aircraft.[6]

Even for Table 2-2, all the due-outs do not apply to aircraft. The items underlying the table all have aircraft applications, but many still have nonaircraft applications, too. A random sample of 40 of the "aircraft items" underlying Table 2-2 showed 24 items (60 percent) with applications only to aircraft and 16 items (40 percent) with applications to both aircraft and nonaircraft systems in the Air Force. That would indicate that the results given in the rule of thumb are, if anything, overstated. They assume (in the way they were derived) that the effect of the increase in high-priority due-outs is absorbed entirely by aircraft. Because so

[6]The data for each of the 176,246 demand-based WSSP/USAF items examined in the study included a listing of up to the first 50 (if there were that many) DLA Weapon System Designator Codes for the weapon systems and other end items to which the item applied. (Table A-4 in Appendix A describes the 176,246-item data base in terms of weapon system applications.) Of the 176,246 items in the data base, 98,472 (55 percent) showed an application to one or more of the following Air Force weapon systems. (Thus, none of the remaining 77,774 items applied to any of these systems):

Attack:	A-7, A-10	Airlift:	C-5, C-130, C-135, C-141
Bombers:	B-52, B-1	Helicopters:	UH-1, H-53, H-60
Fighters:	F-4, F-111, F-15, F-16	Trainers:	T-37, T-38

The 98,472 "aircraft items" account for 64 percent of the total annual demand quantity (units demanded by retail from wholesale) for the 176,246 items in the study and 56 percent of the total number of wholesale unit backorders outstanding as of 31 March 1989.

TABLE 2-2

HIGH-PRIORITY DUE-OUTS FOR DLA ITEMS WITH APPLICATION TO AIRCRAFT

CONUS	Δ due-outs	Baseline	OCONUS	Δ due-outs	Baseline
Langley (1st TFW - F-15)	44	284	Clark (3rd TFW - F-4)	34	727
England (23rd TFW - A-10)	4	15	Bitburg (36th TFW - F-15)	5	94
Little Rock (314th TAW - C-130)	37	191	Bentwaters (81st TFW - A-10/F-16)	5	76
Minot (5th BW - B-52/KC-135)	25	148	Kunsan (8th TFW - F-16)	3	43
Randolph (12th FTW - T-37/T-38)	9	34	Elmendorf (AAC - TAC/MAC)	9	188
			Total	175	1,800

many DLA items have applications to both aircraft and nonaircraft systems, such is not necessarily the case.

To correct this problem, for items with applications to aircraft it would be necessary to know what percentage of their retail-level "point-of-use" demand comes from aircraft (including aircraft components). Because such information is generally not collected for consumable items, it was not available for this study. With that information, we could have prorated due-outs – like those in Table 2-2 – to show more precisely how consumables affect weapon systems alone (e.g., aircraft) as opposed to all the systems to which they apply. In any case, the rule-of-thumb estimates represent upper bounds on aircraft effects. Because those effects are still relatively small, they tell us something useful we didn't know before.

Among the various kinds of "demand-by-weapon-system" information that DLA plans to obtain eventually under SIWSM, such "point-of-use" information, telling whether the demand is aircraft-related or non-aircraft-related (i.e., weapon-system-related or non-weapon-system-related) is the most important. It is precisely the information DLA needs to meet its SIWSM goals.

In this vein, the SIWSM plan for consumables is to include "weapon system" information on replenishment requisitions flowing from retail to wholesale. Taken literally, that would be difficult to do when the requisition is for a quantity greater than one and reflects demands that may have come from many different systems – a situation that is the norm for consumables. The SIWSM concept, however, was motivated primarily by developments in the reparables world. There, when a base requisitions from the depot, it usually requisitions one unit to replace a broken unit being sent back for repair. In that situation, it is easy to note on the requisition the "point-of-use" demand information describing the nature of the end item that needs the part. For consumables, the fact that replenishment quantities are usually greater than one represents only a technical problem in how to format the weapon system information on a requisition. The intent is to obtain "point-of-use" demand information of the type described above.

THE CONSUMABLE LRU EFFECT

Tables 2-1 and 2-2 show high-priority due-outs for consumables in both their roles – as consumable LRUs that apply directly to their parent systems and as consumable repair parts that apply to other components which, in turn, apply to the parent systems. In this section, we focus on consumable LRUs alone – the items that by themselves can directly affect the mission capability of their parent systems because they apply directly to those systems.

What makes high-priority due-outs for consumable LRUs interesting is that they are the "horror stories" – the situations in which the lack of a cheap, consumable item directly causes an expensive end item or weapon system to be either partially disabled or grounded. A good example occurred in May 1988 during the Coronet Warrior III exercise conducted by the Air Force's Tactical Air Command. On the second day of the 30-day exercise, an F-16 was grounded when a weight-on-wheels (WOW) switch failed in the left main landing gear. Because the deployed squadron's WRSK had no WOW switches (the rules of the exercise limited the unit to the spares in its WRSK), the aircraft entered NMCS status and remained so for the full 30 days. The WOW switch for the F-16's main landing gear is a $270 item (rather expensive as DLA items go) managed at DESC. If it malfunctions or fails on landing,

the F-16's flight control computer – because it detects no weight on the wheels – will operate as though the aircraft were airborne. Under those conditions, the aircraft cannot be launched again.

The method for identifying a consumable LRU is to look at the lowest level of maintenance (depot, field, or organizational) authorized to remove and replace the item – information provided by Source, Maintenance, and Recoverability (SMR) codes. SMR codes are uniform, DoD-wide, six-position codes whose meaning and use are defined in joint DoD regulations.[7] The third position of the SMR code identifies the lowest level of maintenance authorized to remove and replace the item: "O" for organizational, "F" for intermediate (field-level or "back shop"), and "D" for depot-level maintenance. The logic is that if organizational-level (e.g., flightline) maintenance can remove and replace the item on a given weapon system or end item, then the item is an LRU – a "line replaceable unit" that applies directly to that system.

As the last point suggests, SMR codes do not apply to items in isolation but to item/end-item combinations. If an item has multiple applications to different end items, or even to the same end item, it may be an LRU in some applications but not in others. More than 70 percent of the items we studied had applications to more than one end item (see Table A-4 in Appendix A for a breakout). To summarize the SMR information for each item, therefore, we assigned it an "LRU factor" equal to the relative number of times an "O" appeared in the third SMR position in relation to the total number of times an "O" or an "F" appeared. (We are interested in prorating due-outs at *bases*, where only O- and F-level removals can take place. D-level removals occur at depots.) The LRU factor gives us a rough estimate of the percentage of the item's total due-outs (all priorities) that are LRU-type due-outs. The estimate is rough because it assumes that demands for an item are equally spread among the different systems that use it. Again, the "point-of-use" demand information needed to avoid having to make this assumption is not currently available and is precisely the information DLA needs to refine its estimates of weapon system effects.

We now want to modify our results on high-priority due-outs overall and focus on the subset of high-priority, consumable-LRU due-outs. These are the due-outs

[7]See, for example, DLA Regulation 4100.6, *Joint Regulation Governing the Use and Application of Uniform Source Maintenance and Recoverability Codes.*

that correspond directly to holes on end items and weapon systems. Table 2-3 presents the results.

TABLE 2-3

HIGH-PRIORITY, CONSUMABLE LRU DUE-OUTS FOR DLA ITEMS

CONUS	Δ LRU due-outs	Baseline	OCONUS	Δ LRU due-outs	Baseline
Langley (1st TFW - F-15)	31 - 61	195 - 389	Clark (3rd TFW - F-4)	26 - 51	558 - 1,115
England (23rd TFW - A-10)	2 - 4	8 - 15	Bitburg (36th TFW - F-15)	3 - 6	55 - 109
Little Rock (314th TAW - C-130)	30 - 59	163 - 325	Bentwaters (81st TFW - A-10/F-16)	9 - 17	189 - 378
Minot (5th BW - B-52/KC-135)	14 - 27	78 - 156	Kunsan (8th TFW - F-16)	7 - 13	152 - 304
Randolph (12th FTW - T-37/T-38)	5 - 10	19 - 37	Elmendorf (AAC - TAC/MAC)	7 - 13	127 - 253

Table 2-3 gives ranges rather than specific values because we do not know what percentage of high-priority due-outs are LRU-type due-outs. All we know is that 20 percent of the total number of due-outs at Air Force bases for DLA items are high priority. That gives us an upper bound on the number of LRU-type due-outs and explains why the right-hand numbers in Table 2-3 match the numbers in Table 2-1. We get the lower bounds by noting that whatever portion they represent, LRU-type due-outs have to represent a greater portion than repair-part-type due-outs. Thus, we can halve the numbers in Table 2-1 to get the lower bounds in Table 2-3.

How do we know that more high-priority due-outs are LRU-type rather than repair-part-type? Because the existence of spare reparables in the system prevents many repair-part-type due-outs from being assigned a high priority, but no such buffer exists for LRU-type due-outs. In the rule of thumb, the increased sensitivity of aircraft to consumable LRU due-outs reflects the preponderance of LRU-type due-outs in the high-priority category. If high-priority due-outs were evenly split between LRU-type due-outs and repair-part-type due-outs, aircraft would be equally sensitive to across-the-board increases in retail due-outs, which they are not. We conclude that half or more of the truly high-priority due-outs – i.e., due-outs directly causing NMCS or PMCS conditions – are consumable LRU-type due-outs.

METHOD

To buttress the findings presented so far, we take time here to review the overall method of the analysis, pulling together some of the key aspects that have been described along the way. If DLA assumes responsibility for all the consumable items in DoD, the Agency's effect on readiness will change, but the methods of this study will remain valid. If DLA wants to continue to measure and monitor its effect on readiness – a goal particularly important as it assumes greater supply responsibilities – the methods of this study can be used. A more detailed, technical description of the methodology, including sources of data and values, modeling assumptions, and methods is given in Appendix B.

The underlying data base for the study consists of the 176,246 demand-based items in DLA's WSSP/USAF program as of the end of March 1989. Although these are not all of the 2.5 million hardware items DLA manages, or even all the 1.2 million items the DIDS catalog shows as being used by the Air Force, they are enough to capture the major effects of DLA's wholesale performance on Air Force readiness – and probably enough to capture DLA's effect on all aircraft-sized systems in the DoD. To support this assertion, Table 2-4 shows that the 176,246 items in the study accounted for 37 percent of the *total* number of outstanding backorder lines for *all* DLA hardware items at the end of March 1989 across *all* of DLA's customers – Air Force, Navy, Army, Marines, and others combined.

TABLE 2-4

DLA BACKORDER LINES COVERED BY THE DATA BASE

Supply Centers	MILSTEP backorder lines	% of total	176,246-item data base backorder lines	% of total
DISC	267,423	51	121,498	62
DCSC	110,493	21	26,511	14
DGSC	81,988	15	23,853	12
DESC	66,882	13	23,771	12
Total	526,786		195,633	

Table 2-4 also shows that backorder lines for the items in the study break out by DLA Supply Center in proportions roughly equivalent to how they break out for all hardware items at DLA (see Appendix A for various descriptions of the data base by Supply Center). In terms of capturing the items that really matter to the Air Force, 70 of 100 items identified on AFLC "DLA Top 25" reports to the DLA Weapon System Support Office (DWSSO) in February 1989 are in the 176,246-item sample. The "Top 25" reports identify the 25 items at each of DLA's four hardware centers responsible for the set of backorders for DLA items that the Air Force is finding most troublesome.

Both DLA and the Air Force know that not all the DLA-managed items with applications to Air Force weapon systems are in DLA's WSSP/USAF program. At the time of this study, AFLC and DLA were working jointly to identify additional items for inclusion in the program – primarily for older weapon systems deployed before the WSSP was started in 1981. Adding more WSSP/USAF items could change the study results, because the total dollar value of WSSP/USAF safety levels would increase, and total EBO quantities would be larger and might show different percentage changes in response to changes in wholesale safety levels. However, unless very large numbers of additional items are added, with demand characteristics quite different from the items already in the program, big changes in aircraft effects are not likely. The numbers of high-priority, retail-level due-outs for consumables shown in Tables 2-1, 2-2, and 2-3 would increase somewhat.

We constructed a wholesale-level inventory model, with mathematics and rules similar to those in DLA's SAMMS, to predict the percentage change in wholesale-level unit EBOs, if safety levels for the 176,246 items were changed. DLA-supplied data included a statement of the SAMMS safety level for each of the 176,246 items as of the end of March 1989. After reducing the safety level for each item by 20 percent, the model showed that wholesale unit EBOs for the system (i.e., the collection of items as a whole) would increase by about 25 percent.

A 25 percent increase in wholesale EBOs for demand-based WSSP/USAF items adds about 5 days to the average depot delay experienced by Air Force bases worldwide when ordering those items from DLA. Using retail-level stockage data supplied by the Air Force for 10 bases – 5 overseas and 5 in CONUS – we constructed retail-level models to predict how outstanding base-level due-outs would change if there were no changes in retail stockage levels and order-and-shipping

times (OSTs) increased by 5 days. For the CONUS bases, OSTs were increased from 15 days to 20 days for every item; for the OCONUS bases, they were increased from 60 days to 65 days. The baseline OST values of 15 days (CONUS) and 60 days (OCONUS) were derived from data for Kunsan, Minot, England, and Little Rock AFBs appearing in a 1983 AFLMC study.[8]

The stockage data for each of the 10 bases came from AFLMC. AFLMC provided a file for each base, current as of March 1989, containing all the DLA-managed, ERRC Code XB3 items on the base stockage list with cumulative recurring demand greater than zero. The NSNs for these items were matched against those for the 176,246 WSSP/USAF items. Table 2-5 shows the percentage of retail records matched at each base. (The total number of items at each base and the number of records that found a match in the DLA data are shown in Table B-10 in Appendix B.) In addition to NSN, the retail data for each item included price, demand, and demand variance information. Unfortunately, the retail data did not include OST information, which is why the uniform values of 15 days and 60 days were used.

TABLE 2-5

RETAIL RECORDS MATCHED AT AIR FORCE BASES

CONUS	% of retail records matched	OCONUS	% of retail records matched
Langley	64.5	Clark	52.9
England	66.6	Bitburg	53.4
Little Rock	61.6	Bentwaters	63.8
Minot	67.0	Kunsan	52.8
Randolph	67.3	Elmendorf	53.5

That not every retail record was matched is not surprising. The base files contain *all* the DLA-managed items (except for the small numbers of ERRC Code XF3 items) on the base stockage lists. That would include NSO items and items not in the WSSP/USAF program – neither of which are included in the 176,246-item,

[8]Maj Douglas J. Blazer, USAF, *Order and Ship Time Study*, AFLMC Report 791001, October 1983, Air Force Logistics Management Center, Gunter AFB, Alabama 36114.

demand-based WSSP/USAF file from DLA. Across all 10 bases, the total number of distinct NSNs that found a match was 61,477. (The same NSN may be used at more than one base.)

An important aspect of the analysis is that we added the same 5-day increase in average depot delay uniformly to the OST for every item in the retail models rather than separately computing and adding the increase in average depot delay for each item. First, without individual OSTs, we saw no point in treating each item individually. Second, DLA only controls wholesale stockage levels; the Services independently set their own retail levels. Until wholesale and retail stockage levels are coupled in the multi-echelon sense (so that the right "split" is achieved between wholesale and retail levels for a given total level in the system), the technique for computing overall average depot delay is a reasonable compromise for wholesalers – certainly for wholesalers of consumables.

Both the number and percentage change in outstanding, base-level due-outs played a role in determining readiness effects. The percentage change in due-outs overall, along with additional retail-level data from the Air Force, determined the increases in average waiting times that maintenance customers at bases and depots would experience when requesting items from supply. Those increases – about 0.5 day at bases and about 1.0 day at depots – were added to base and depot repair times for reparables in the AAM. The model then computed the ultimate effects on aircraft availability, taking into account the buffering effect of spare reparables.

The change in the number of outstanding, base-level due-outs for each item was factored by the high-priority-to-total-due-outs ratio of 20 percent to obtain the results given in Tables 2-1, 2-2, and 2-3. When they were set up, the retail models were calibrated so that they predicted quantities of high-priority due-outs comparable to those that exist in the real world (as reflected in Air Force M32 supply summaries). The calibration was accomplished by halving the estimates of demand variance derived from the retail data.

IS DLA SUPPORT IN BALANCE WITH AIR FORCE SUPPORT?

Part of DLA's responsibility under SIWSM is to try to balance its support for Air Force systems with the support the Air Force provides to itself. But to make a fair comparison between Air Force supply support and DLA supply support, we need a measure that looks only at supply effects, rather than at the effects of the entire

logistics system – supply, maintenance, distribution, and other functions – working together. After all, the only things that DLA managers can control are wholesale stockage levels; they cannot control (nor should they or the Air Force count on) the rest of the logistics system to adjust for supply imbalances that may exist between the Air Force and DLA.

This means we cannot use the rule-of-thumb results, because they do not hold everything else in the logistics system "constant." They represent the real-world, bottom-line effects of a change at DLA, after the rest of the logistics system has done everything it can to minimize the number of NMCS and PMCS aircraft (see the discussion in the last section of Chapter 1).

What we will use is the supply measure of aircraft availability, as computed by the AAM. The AAM is a weapon-system-oriented *supply* model. Aircraft availability rates reflect the number of aircraft that can be expected to be not waiting for a spare, given various possible stockage levels for reparable spares. "Available" aircraft in the AAM sense are not the same as FMC aircraft. They may or may not be waiting on maintenance, fueling, armament, crew, or some other function. The AAM does not assume any special effort on the part of maintenance or other logistics functions to fix items faster than usual, redistribute stocks, withdraw items from WRSKs, or concentrate "holes" on as few aircraft as possible by means of cannibalization.

With the set of aircraft availability (AA) targets currently being used by AFLC to compute safety-level requirements for depot-level reparables (DLRs), the Air Force is building spares budgets such that every $1.0 million reduction in DLR safety levels corresponds to a new, lower set of AA rates in which 13 more aircraft become unavailable, out of a nominal fleet of 6,353 available aircraft (see Table 2-6).

Table 2-6 shows the aircraft types in question, the projected primary aircraft inventory (PAI) in FY91, the target AA rate and corresponding number of PAI aircraft (6,353 in total – corresponding to an overall AA rate for the fleet of 86.8 percent), and the additional number of aircraft "lost" (rendered unavailable) by moving down the availability/cost curve for each aircraft by $1.0 million. The 13-aircraft-per-million result is the total of 221 additional lost aircraft divided by the total dollar reduction of $17.0 million in spares investment. Losing 13 aircraft corresponds to lowering the overall fleet AA rate from 86.80 percent to 86.62 percent.

TABLE 2-6

AAM TARGETS AND DELTAS

Aircraft types	Total FY91 fleet sizes (PAI)[a]	Number of aircraft at AFLC target availability (target in parentheses)	Number of additional aircraft "lost" for $1.0 million reduction in reparable safety levels
Attack			
A-7	272	226 (83%)	23.2
A-10	566	509 (90%)	4.2
Bombers			
B-1	92	69 (75%)	0.2
B-52	186	167 (90%)	5.9
Airlift			
C-5	116	87 (75%)	0.8
C-130	606	545 (90%)	1.6
C-135	683	615 (90%)	2.3
C-141	250	220 (88%)	1.5
Fighters			
F-4	360	299 (83%)	8.2
F-15	851	706 (83%)	1.7
F-16	1,630	1,418 (87%)	8.0
F-111	261	214 (82%)	1.0
Helicopters			
H-1	74	55 (75%)	28.0
H-53	44	33 (75%)	1.3
H-60	54	40 (75%)	2.4
Trainers			
T-37	559	486 (87%)	105.0
T-38	714	664 (93%)	26.0
Totals	7,318	6,353 (= 86.8% of 7,318)	221.3

[a] The total Air Force fleet of 9,100 aircraft includes backup aircraft inventory (BAI) as well as PAI aircraft The AAM considers only PAI fleet sizes in its calculations

We cannot use the AAM to get the corresponding numbers for DLA, because the AAM only covers reparables, but we can describe a method to get an approximation. First, we need to generalize the results in Table 2-2 to the worldwide Air Force. Table 2-2 shows, for 10 representative bases, the increase in high-priority due-outs for DLA items with applications to AAM aircraft if DLA makes a $50 million reduction in WSSP/USAF safety levels. The sum of the increases is 175 due-outs. To get the increase worldwide, we multiply by 14, because we are looking at 10 bases and the Air Force has 141 major bases worldwide. That yields an estimate of 2,450 high-priority due-outs worldwide.

Next, we will let W represent the fraction of these due-outs that actually exist on AAM aircraft or aircraft components. (Remember that many of the "aircraft items" underlying Table 2-2 also have application to systems that are not aircraft.) The W factor represents the unknown portion of total, point-of-use, high-priority demand for DLA items that comes from aircraft (or aircraft components).

The quantity $(2{,}450 \times W) \div 50 = 49W$ now represents an estimate of the increase in base-level, high-priority due-outs to aircraft that would be caused by a $1.0 million reduction by DLA in WSSP/USAF safety levels. We can convert this number to an AA rate using an approximating relationship that exists between fleet AA rates and high-priority due-outs to aircraft:

$$AA_{new} = \frac{AA_{old}}{e^{\Delta \text{ LRU EBO}/7{,}318}}, \qquad \text{[Eq. 2-1]}$$

where 7,318 is the total AAM fleet size.[9]

[9]Equation 2-1 is based on the approximation:

$$AA_{fleet} \approx \frac{1}{e^{\text{LRU EBOs/fleet size}}},$$

which says that product formula availability rates are closely approximated by one over the natural antilogarithm of the number of LRU EBOs divided by the fleet size. For a discussion of this approximation, see Appendix A, "Availability Rate and Expected Backorders Per Aircraft," in the LMI report by T. J. O'Malley, *The Aircraft Availability Model: Conceptual Framework and Mathematics*, Task AF201, June 1983.

If we set the AA_{old} value to 0.8680 (the Air Force's overall target for the fleet), and the AA_{new} value equal to 0.8662 (corresponding to a loss of 13 aircraft), we can solve for W:

$$0.8662 = \frac{0.8680}{e^{49W/7,318}}; W = 0.31. \qquad \text{[Eq. 2-2]}$$

This tells us that DLA supply support to aircraft in the Air Force is in balance with Air Force supply support *if* 31 percent of the high-priority demand for DLA items at bases is generated by aircraft or aircraft components. If the percentage of total demand for DLA parts generated by aircraft is greater than 31 percent, say 50 percent, then the Air Force "loses" 21 aircraft for every $1.0 million reduction in WSSP/USAF safety levels, and DLA would be undersupporting in relation to the Air Force. If less than 31 percent of total base demand for DLA parts is generated by aircraft, DLA is oversupporting in relation to the Air Force.

These results reinforce the importance of DLA's obtaining information on the percentage of point-of-use demand generated by aircraft versus nonaircraft. With that information, DLA can answer the balance question, and without it, it can't.

Implicit in the preceding argument is the idea that the correct way for DLA to address the balance question is to check whether the ratio

$$\frac{\Delta \text{ aircraft}}{\$ \ \Delta \text{ in safety levels}} \qquad \text{[Eq. 2-3]}$$

agrees with the corresponding ratio that the Air Force has implicitly set when it chooses AA targets. This approach recognizes that DLA must follow the Air Force's lead in providing weapon system support.

The idea of balance is the DLA safety levels for WSSP/USAF items should support aircraft availability to the same degree – no more or less – as safety levels in the Air Force fore reparables. (We look at Air Force reparables because that is where the Air Force is using availability targets.) DLA would like the Air Force to provide "required" depot response times. This section on 'balance' is suggesting that another way to accomplish the same goal is to set WSSP/USAF safety levels so that the ratios of aircraft per dollar reduction in safety level agree between DLA consumables and Air Force reparables. The depot response time the Air Force

"requires" is the time such that the aircraft-per-dollar ratios for DLA consumables and Air Force reparables agree (are in "balance") in this way.

In availability-based calculations of spares levels, with the AAM for example, the spares level for each item is associated with an availability-improvement-per-dollar-of-stockage-investment cutoff value. The balancing approach gives DLA items the same cutoff value in aggregate that Air Force reparables have in aggregate. It is in that sense that the balancing approach ties DLA EBO targets (which wind up getting defined implicitly) to availability targets. DLA items and Air Force reparables would be in balance in that the marginal costs of gaining availability improvements would be the same for both sets of items.

The larger, DoD-level question of achieving optimum balance between investment in reparables versus consumables is harder: Would it be better to buy more spares and fewer repair parts, or spend more on parts and repairs and less on spares? It is technically feasible to approach the question using the "marginal analysis" technique above, but it is not clear the benefits would be worth the cost in data gathering and model development. Also, as long as different organizationsmanage consumables versus reparables, it is not practical to combine the items in a single inventory model. Given that consumables are much cheaper on average than reparables, perhaps it is enough to let consumables simply follow the Services' lead and let that suffice for achieving balance.

CHAPTER 3

CHANGING THE WAY THE WSSP WORKS

So far we have been talking about the way DLA works today. Chapter 1 is about the role DLA items play in the Air Force; Chapter 2 is about what happens if DLA changes WSSP/USAF safety levels but otherwise leaves the rest of its operating procedures alone. This chapter is about changing the way DLA operates the WSSP – in the spirit of "weapon-system-oriented supply management" – and the savings and performance implications if it does.

VARIABLE SAFETY LEVELS

DLA sets safety levels for WSSP items by assigning each item a SAMMS variable safety level (VSL) calculated by the item's Supply Center, and, for selected items, augmenting that with an additional amount based on a separate calculation for the item itself. Because it is this safety-level-setting procedure that we propose to modify, we will describe it in more detail.

Not only DLA, but every wholesale consumables management organization in DoD – including the Army, Navy, and Air Force Stock Funds – computes safety-level requirements for consumables following DoD Instruction (DoDI) 4140.39, *Procurement Cycles and Safety Levels of Supply for Secondary Items.* Published in July 1970, the DoDI addresses nonreparable secondary items (i.e., consumables) and describes the basic nature of the mathematical inventory model to be used at ICPs. The suggestions made in this chapter for DLA are natural extensions of DoDI 4140.39 methodology (in fact, they require no change in the policy) and can be applied to wholesale consumables management as practiced by all the Services.

The basic VSL approach is to calculate for a collection of items as a group – rather than for items individually. The objective, for any given total investment in stockage levels, is to minimize the total number of EBOs for the collection rather than to control EBOs for each item. The safety levels derived this way have come to be called "variable" because each item generally receives a different safety level,

reflecting the item's demand, demand variance, and price characteristics in relation to those of the other items in the group.

At a DLA Supply Center, the group of items in a VSL calculation is the collection of items managed by the center. The idea is that whatever the total investment in stockage levels, the goal is to minimize the total number of outstanding backorders on the center's books for that investment. This is an understandable and natural approach from the point of view of the center, but one that makes it difficult for DLA to either know or control the support being provided to particular weapon systems or end items.

In an attempt to remedy this problem, items in the WSSP are authorized to receive "augmented VSLs." If a WSSP item is selected, a VSL is calculated separately for the item by itself, apart from the system calculation done at the center. The calculation is usually done by selecting a supply availability target for the item and computing a safety level to meet the target. This safety level is compared to the system-based VSL from the "whole-center" calculation, and the larger of the two safety levels is assigned to the item.

Augmented VSLs are not widely used, but they are used and they are not cheap. In FY89, for example, of the 970,000 items DESC manages, 143,000 were candidates for augmented safety levels, and about 7,000 actually received higher levels. The combined cost of the *increases* was $40.0 million.[1]

GROUPING ITEMS BY WEAPON SYSTEM

For purposes of calculating VSLs, our proposal is to group items by weapon system rather than by Supply Center. (In the Navy, both the Ships Parts Control Center and the Aviation Support Office have experimented with this approach by instituting "weapon-system-segmentation" programs for system-unique items on a selected number of high-value weapon systems.) To see what this might mean, we did an experiment on the collection of items in the WSSP/USAF program that have applications to the F-16.

Of the 176,246 items in the study, 19,845 have applications to the F-16. From SAMMS/DLA Item Data Bank (DIDB) data as of March 1989, these 19,845 items

[1]Information provided by Mr. Anthony Galluch of Defense Electronics Supply Center, August 1989.

accounted for $128.5 million in WSSP stockage levels – $98.5 million in leadtime demand pipelines and $30.0 million in safety levels. Some of these safety levels reflect augmented VSLs; most probably do not. With these safety levels, EBOs (wholesale unit EBOs) for the 19,845 items total 745,309.[2] The experiment is to see what happens if we treat the 19,845 F-16 items as the collection (or system) upon which we perform the SAMMS VSL calculation. What happens to safety-level investment and system EBOs?

By treating the 19,845 F-16 items as the system and computing safety levels to minimize EBOs for *that* collection, we found it possible to

- Reduce safety-level investment by two-thirds (from $30 million to $10 million)

and at the same time

- Reduce wholesale EBOs by more than 25 percent (from 745,000 to 550,000). (In terms of aircraft, this "gets back" about 2 of the estimated 20 to 25 F-16s that are in NMCS or PMCS status on average worldwide for DLA parts.)

This is a startling result. If it holds up for other systems in the WSSP/USAF program (we looked only at the F-16), it would mean that DLA's current method for setting WSSP safety levels is highly inefficient, and the Agency should seriously consider changing the way it sets WSSP safety levels.

How is it possible to save money and, at the same time, improve performance?

Under current WSSP safety-level-setting methods, there is no reason to expect current safety levels to be particularly efficient at minimizing EBOs *for the collection of 19,845 F-16 items.* First, F-16 items are spread across the four Supply Centers:

- DESC – manages 42.6 percent of F-16 items
- DISC – manages 42.4 percent

[2]Remember that EBOs represent an estimate of the *average* value of the number of unit backorders outstanding at any given time. EBOs are computed with an inventory model as a function of safety levels, demand rates, demand variance, and other item factors. They represent the key output measure that supply managers try to control by the stockage levels they set. The actual number of outstanding unit backorders for the 19,845 items at the end of March 1989 was considerably larger than the EBO estimate of 745,309. The difference, however, is due to the presence of a large number of "unexpected" backorders whose existence, the evidence suggests, has nothing to do with wholesale stockage levels. The problem of unexpected backorders is the subject of Chapter 4.

- DGSC – manages 8.1 percent
- DCSC – manages 6.9 percent.

That means in the current SAMMS VSL computation that backorders for F-16 items are being traded off against backorders for many non-F-16 items, including items not even in the WSSP. Second, even if every one of the 19,845 F-16 items has received an augmented VSL, tradeoffs between demand, demand variance, and price have not been made. The augmented VSL calculation is done for each item by itself and misses the benefits of *system* EBO minimization that are central to the VSL approach.

The appeal of the "group-by-weapon-system" idea is that it is a natural and fairly easy way to introduce a true weapon-system orientation into the WSSP – something it does not have now. All the WSSP can do today, if it is willing to spend the money, is set augmented VSLs to achieve a supply availability target for all the items that apply to a given weapon system. But that is not what weapon-system-oriented supply management is, or should be, about. A wing commander who is told wholesale supply is delivering a 94 percent fill rate for F-16 items knows no more than before about whether that's enough, too much, or not enough to meet readiness requirements. *Setting safety levels in the WSSP by grouping items by weapon system is the appropriate DLA response to the SIWSM initiative.*

Of course, questions must be answered about item essentiality, common components, and organization – all of which we will talk about shortly. First, let's back up and review exactly what we did in our calculation.

We began with the SAMMS safety levels in the March 1989 file for the 19,845 F-16 items. Using a SAMMS-like wholesale inventory model, those safety levels imply an average of 745,000 outstanding unit backorders. We then did a system VSL calculation for the collection of 19,845 items, using 745,000 as the "beta" constraint on EBOs for the system.[3] In effect, we were seeking to get back a total of

[3]The mathematics for the SAMMS VSL inventory model (and the wholesale consumable inventory models used by the Air Force, Navy, and Army, as well) are described in a paper by Victor J. Presutti, Jr., and Richard C. Trepp, "More Ado About Economic Order Quantities (EOQ)," *Naval Research Logistics Quarterly*, Vol. 17, No. 2, June 1970. The method in the paper served as the model for DoDI 4140.39 on how wholesale safety-level requirements for consumables were to be computed. The basic approach of the Presutti/Trepp method is to minimize ordering and holding costs in an inventory system (i.e., a collection of items), subject to a constraint, *beta*, on the average number of outstanding unit backorders in the system.

745,000 EBOs, but to do so with a smaller total safety-level investment by taking the system approach. We wound up with fewer than 745,000 EBOs because of additional limitations placed on safety levels – limitations identical to ones in SAMMS.

Following DoDI 4140.39, SAMMS (and the other wholesale consumable inventory models in the Services) limits the safety level for any item to no greater than leadtime demand or three standard deviations of leadtime demand, whichever is less. DoDI 4140.39 also allows DLA and the Services to set an item's safety level to zero when the model yields a negative safety level (i.e., calls for the reorder point to be less than demands in a leadtime). The effect of these rules (which are reasonable ways to deal with uncertainties and possible extremes in the data) is to make the beta value a "control knob" rather than an active constraint. Lowering beta will increase safety levels and raising beta will decrease them; however, at the end of the calculation, EBOs for the system will generally be different from the EBO target (beta) going in. In our experiment, after performing the system calculation, 8,285 items had negative safety levels that were reset to zero. Although EBOs went up for some items and down for others, the effect overall was to lower EBOs for the system from 745,000 to 550,000.

Table 3-1 shows how the safety-level mix changed. "Old" in the table refers to the March 1989 SAMMS safety levels for the 19,845 items; "new" refers to the safety levels derived from the system VSL calculation.

TABLE 3-1

HOW THE SAFETY-LEVEL MIX CHANGES

Old versus new comparison	Count
Old = 0	972 times
New = 0	8,389 times
Old = 0 = new	755 times
Old = 0, new > 0	217 times
0 < old = new	705 times
0 < old > new	13,330 times
0 < old < new	4,838 times
0 < old and |new – old| ≤ 10	3,578 times

Given that the total investment in safety level is $20 million smaller, it is not surprising that most of the time the new safety levels are smaller than the old safety levels. This did not always happen, however, because of the mathematics of system optimization. In the data, a total of 2,416 items with nonzero demand and demand variance had old safety levels that fail to comply with the SAMMS rule about being no bigger than the smaller of leadtime demand and three standard deviations of leadtime demand. (The problem of inconsistencies and contradictions in the SAMMS data is discussed at the end of Appendix A.)

To give a glimpse of the effects at the individual item level, Table 3-2 shows the old and new safety levels for five items, chosen from the collection of 19,845. The "QFD" (quarterly forecasted demand) and "MADLT" (mean absolute deviation in leadtime) entries are measures of demand and demand variance, respectively. The "WSIC" entries show the weapon system indicator code (WSIC) reflecting item essentiality, which will be discussed in greater detail shortly.

TABLE 3-2

OLD VERSUS NEW SAFETY LEVELS: ITEM EXAMPLES

Item	QFD	Price (dollars)	MADLT	Old EBO	Old safety level	New safety level	New EBO	WSIC
1	26	120.02	12.5	0.1	24	0	1.2	F
2	763	0.53	54,723.4	21,782.0	2,859	2,859	21,782.0	P
3	207,071	0.58	127,886.6	19,184.8	10,872	246,780	2,380.0	F
4	30,388	0.05	11,622.4	0.9	67,455	36,496	18.7	F
5	2,743	0.04	1,485.1	2.5	3,077	3,439	1.9	F

Note: F = renders end item operable; P = failure does not affect end-item operability.

Table 3-2 shows that system VSL calculations are driven not by any single factor (such as price), but by the interplay between demand, demand variance, and price to come up with the best mix of safety levels for the system. In particular, note that the new safety level for a very inexpensive item – Item 4 at 5 cents – is smaller than the old safety level, demonstrating that it is not the case the system VSL approach "just buys a lot of cheap items." Item 4 gets less safety level because its demand and demand variance are low enough to justify less safety level, even though the item does not cost very much. In comparison, the demand and demand variance

for Item 3 are such that the new safety level is quite a bit larger than the old safety level – even though, compared to Item 4, Item 3 is more than five times as expensive (albeit still inexpensive at 58 cents).

The traditional complaints about VSL methods are really trying to express an important but subtler problem than that of bias toward low-cost items. Intuitively, people recognize that EBO minimization for a system (collection) of items only makes sense *if the system is defined so that every backorder is equivalent to every other backorder*. Somehow the penalty associated with an outstanding backorder for any one item in the system should be equivalent to that of a backorder for any other item in the system. People sense that this is often not the case for more expensive items: "A backorder for a $200 WOW switch is more serious than a backorder for a $2.00 attaching clamp," and they shorthand that intuition by saying the VSL approach "doesn't buy enough of the $200 items."

What is actually important is the function of the part – not its price. If lack of an attaching clamp grounded an F-16 just as decisively as lack of a WOW switch, and DLA had $200 to spend after buying the pipelines for both items, it does make sense (assuming the two items have comparable demand patterns) to buy more clamps rather than one more WOW switch – because that will reduce EBOs for the fleet by a greater amount and result in more available aircraft for the investment. But if the aircraft can still fly and do most of its missions with a broken or missing clamp but not without an operational WOW switch, then it may be wiser to buy another switch and pass on the extra clamps.

We have arrived at the subject of "item essentiality."

ITEM ESSENTIALITY

Ever since VSL methods were introduced, DoD supply managers have wrestled with the problem of defining the penalties and "penalty costs" associated with backorders. Item essentiality schemes were invented to try to deal with the problem. DLA's scheme is typical.

The entries in the rightmost column in Table 3-2 are WSICs that DLA uses to classify the "essentiality" of items in the WSSP. They represent a combination of the importance of the parent system or systems to which the item applies and the ability of the item to affect the operability of the parent system if the item fails or needs to be

replaced. Items coded "F" have applications to "most important" or "most critical" systems (based on Force Activity Designators and other criteria) and are supposed to render the system inoperable if they fail or need to be replaced. Items coded "P" apply to "most critical" systems, but are supposed to have no effect on the operability of the system.

Table 3-3 presents the 3×3 matrix DLA uses to define WSICs. The official definitions for the numeric item essentiality codes in Table 3-3 are shown in Table 3-4.[4]

Given heterogeneous collections of items upon which they perform system VSL calculations, supply managers at DLA (and throughout DoD) have tried to use item essentiality schemes as the basis for assigning different "weights" to the items they manage, hoping that by using those weights in their VSL calculations, they can, in effect, achieve the "right" balance among backorders for different items, recognizing that the backorders are not all equally serious.

Other weighting schemes – in the Air Force's SSD and at DESC, for example – have used average requisition size and requisition frequency to give backorders different weights. In its formulas, the SSD multiplies by one divided by the square root of average requisition size – giving backorders for large-requisition-size items less weight. Although it is tempting to think that such items will generally be less essential in military terms (How important can backorders be for all those metal screws we keep issuing to flightline benchstock?), there is certainly no guarantee. And, it is interesting that this scheme tends to *increase* supply availability rates because it improves supply's position for filling lots of small requisitions. DESC accomplished the same thing by tying weights to requisition frequency – the more requisitions per month, the higher the relative weight.

None of these weighting schemes, however, has satisfactorily solved the problem of getting the "right" mix of backorders while simultaneously preserving the optimality of the system calculation. *No weighting scheme can do that.* In the VSL

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[4]These definitions appear in *DLA Supply Operations Manual* (DLAM 4140.2, Volume II, Part 3, Appendix A-38), and are based on the definitions in Military Standard (MILSTD) 1388-2A, which defines the data elements of the DoD uniform Logistics Support Analysis Record (LSAR). As a result, the Army, Navy, Air Force, and DLA all employ similar item essentiality schemes. A recent DoD Directive (DoDD) 4140.59, *Determination of Requirements for Secondary Items after the Demand Development Period,* June 1988 provides uniform DoD policy on the use of item essentiality in determining stockage-level requirements. The Services assign item essentiality codes to the DLA-managed items they use.

TABLE 3-3

DLA WEAPON SYSTEM INDICATOR CODES (WSICs)

Weapon system group code	Item essentiality codes		
	1	5, 6, or 7	3 or blank
Most critical	F	H	P
Critical	G	J	R
Least critical	K	M	S

TABLE 3-4

NUMERIC ITEM ESSENTIALITY CODE DEFINITIONS

Code	Definition
1	Failure to this part will render the end item inoperable.
3	Failure to this part will not render the end item inoperable.
[illegible]	Item does not qualify for the assignment of Code 1 but is needed for personnel safety.
6	Item does not qualify for assignment of Code 1 but is needed for legal, climatic, or other requirements peculiar to the planned operational environment of the end item.
7	Item does not qualify for assignment of Code 1 but is needed to prevent impairment of or the temporary reduction of operational effectiveness.
Blank	Same as Code 3 or appropriate Service has not assigned an essentiality code.

method, the whole point of the mathematics of system optimization (the mathematics being the Lagrange multiplier method of multivariable calculus) is to come up with precisely the right mix of safety levels, different from item to item, to minimize EBOs for the collection. A finite collection of different item weights, multiplied times the Lagrange multiplier in each item's safety-level formula, is highly unlikely to achieve the optimal solution that is guaranteed if the items are simply grouped by

essentiality first, and VSL calculations are done separately on each group (without using weights).

Indeed, if SIWSM has a core idea, it is that *when minimizing system backorders, items should be grouped by weapon system when safety levels are calculated.* Backorders for a collection of items at least have a chance to be militarily equivalent if the collection is defined by the fact that all the items in it apply to the same weapon system.

We do not imply that grouping items by weapon system, as we have done with the 19,845 F-16 items in our experiment, is guaranteed to be enough. Even within such a group, backorders still may not be militarily equivalent. In particular, we have already seen how consumables that apply as LRUs can have a substantially larger effect on readiness than consumables used as repair parts. For that reason, we recommend that after grouping items by system, DLA should further distinguish between LRUs and non-LRUs before doing system VSL calculations.

We did not make that distinction in our F-16 experiment because we did not have the raw SMR data to tell us whether each F-16 item was an LRU or not. (All we had was what we asked DLA to provide – summary counts of the number of times each item was O-, F-, and D-level removable across all its applications.) DLA does have the mechanism in place, however, to get the necessary SMR data to identify whether an item is an LRU on a given system. Supply support requests (SSRs) already identify the end item or weapon system being supported and include a field for transmission of portions of the six-position SMR code. The Weapon System Support Office at DLA has initiated an effort to make room for the third position of the code, which tells the lowest level of maintenance authorized to remove and replace the item (thereby identifying whether the item is a "line replaceable unit" on the system).

Beyond distinguishing between LRUs and non-LRUs, DLA may wish to further subdivide based on item essentiality. For example, items with an item essentiality code of 3 (items that have no effect on the operability of their parent systems) perhaps should have zero safety level as a matter of policy – carrying only a pipeline level to cover average demand.

If DLA does elect to subdivide further based on item essentiality, the WSICs now in SAMMS will have to be reviewed. For those items with applications to more

than one system, the assigned WSIC is the "highest" one and may not apply to the weapon system in question. Further, evidence indicates that the Services are not assigning item essentiality codes properly. The WOW switch described earlier, for example, can most definitely ground an F-16, but it has a WSIC of "P" in SAMMS, meaning it supposedly has no effect at all on the aircraft. Another WSSP/USAF item is a small cleaning brush for gun barrels, with multiple applications to different systems. The brush carries an "F" WSIC in connection with its use on the Chinook helicopter and the Harrier vertical-takeoff aircraft. Clearly, the rules governing item essentiality (Tables 3-3 and 3-4) were not followed for these two items.

There are also questions for whole classes of items. Of the 176,246 NSNs in the study, 41,227 (23.4 percent) are in Federal supply classes that identify them as fasteners of one sort or another: screws, bolts, studs, nuts, washers, nails, keys, pins, and rivets. Of these items (which account for 35.8 percent of the total annual wholesale unit demand for all the items in the study), 22,876 (55.5 percent) have an item essentiality code of 1. Of these, 16,727 have aircraft applications. The remaining 6,149 items apply only to nonaircraft systems. That is, they are nuts and bolts for various pieces of ground equipment. Are all these items truly essential, or have some been classified that way to improve supply support?

A final comment on using item essentiality to subdivide weapon-system groups: Dividing a given collection of items into a very large number of subgroups creates the risk of losing the benefits of *system* backorder minimization. In the extreme case, every item becomes a group of one, and no system benefits are realized. When using item essentiality in computing safety levels for wholesale consumables, therefore, DLA (and DoD for that matter) should strive to "keep it simple." Does the item have any effect on the operability of the system or not? If it doesn't, then no safety level. If it does, then is it a grounding item or one that only impairs some missions? Grounding LRUs could then be one collection, and the impairing items – LRUs and otherwise – could be the other. That would produce three groups: items with no effect, grounding LRUs, and everything else. Such a scheme would yield subgroups large enough to preserve the benefits of the system approach, and, by keeping things simple, might make it easier for the Services to do a better job of coding items than they appear to be doing now. More accurate identification of DLA grounding LRUs by the Services will help DLA do a better job with these items, which can have a direct influence on readiness.

COMMON COMPONENTS

A large number of WSSP/USAF items (125,680 of the 176,246 items in the study, accounting for 93 percent of total annual unit demand) apply to more than one weapon system or end item. These "common components" have many logistical advantages. They simplify maintenance across systems, and they save money in supply. The mechanics of pipelines and stockage levels are such that a single level for a common component, supporting total demand, will provide a given level of support more cheaply than separate levels providing the same support. There should be one wholesale level for each common component, therefore, no matter how many systems use the item. How can DLA set single wholesale safety levels for common items if it adopts a weapon-system-grouping approach?

For the 19,845 F-16 items, for example, the average number of associated WSSP weapon system/end items (both Air Force and otherwise) is 17. How do we set the safety level for an item that applies to the F-16 and 16 other systems?

One possible approach is suggested in Figure 3-1.

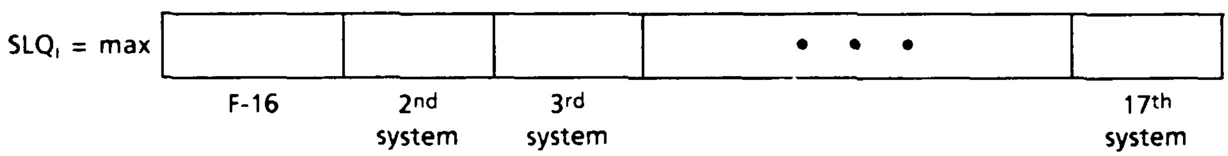

FIG. 3-1. SETTING THE SAFETY LEVEL FOR A COMMON COMPONENT

As a member of the F-16 collection, the item gets what we could call its "F-16 level." We would store that number in an array indexed by the number of applicable systems for the item. Then, as part of a second system, the item would have a second level, determined by performing a system VSL calculation on the items that applied to the second system. We would do the same for the third system, and so forth.

Once all the different system calculations have been done, the final step would be simply to choose a level from the completed array. A sure-fire approach would be to assign the largest level computed. That would guarantee that every system is supported at least to its "required" level. (Underlying each system calculation is

some sort of weapon system target, which we discuss further in the next section on "Organization and Budgeting.")

As an alternative, DLA could choose the largest level that appears, but only from among the most critical systems. The weapon system group codes currently used in defining WSICs could serve to identify those systems.

The procedure we have been talking about thus far assumes that in any given system calculation, the *total* demand on wholesale for the common item – coming from *all* using systems – is used. That's what SAMMS uses now for common components and is what we used in the experiment of F-16 items. *For common components, that is the right thing to do.* While it is tempting to compute the system level for a common component using only that portion of its demand that comes from the system, that approach would be a mistake. It would, in effect, "de-commonalize" the item, producing multiple system levels that are not as efficient as a single level based on total demand.

If DLA begins to get information on retail-level, point-of-use demand by weapon system under SIWSM, that information can be used in common component calculations – but not to prorate demand.

In a system calculation, if DLA multiplies a common component's total computed EBOs by the point- use demand percentage for the system in question, it gets the correct EBO value for the component on *that* system. That value would be important if safety levels had to be determined by setting precise system EBO targets (beta targets). However, as long as system EBO targets are used only as control knobs to raise or lower safety levels, DLA can use the "total demand" approach for common components and successfully find optimal safety-level mixes by system.

In the end, after all the system calculations are completed, DLA must still decide on a final, single level for each common component. Having to explicitly decide in this way on levels for common components is something new, but it offers a chance to save money and improve weapon system support. Under today's method, DLA *implicitly* assigns common component levels that may or may not be appropriate for the weapon systems and end items involved.

ORGANIZATION AND BUDGETING

The problems of item essentiality and common components are technical problems that can be managed. If DLA wants to change the way it computes WSSP safety levels, the real challenges are organizational.

As we saw for the 19,845 F-16 items, no single Supply Center is likely to manage all the DLA items that apply to any given system. That means the Centers will have to share data and cooperate with one another to compute and assign weapon-system-based VSLs for WSSP items. It is probably both necessary and inevitable that a headquarters office will have to be involved as an arbiter, policymaker, and perhaps even level-computing body, advising Supply Centers on safety levels for WSSP items.

Taking the system-oriented approach to WSSP safety levels will also change how annual budget requirements are computed and justified. Now, each Supply Center has evolved a procedure for setting safety levels and computing budget requirements for all its items, including WSSP items. The weapon-system-oriented approach would require the use of system EBO targets (rather than a single EBO target for the whole Center), which would serve both as the basis for safety-level calculations and as the justification for the safety-level portion of budget requests.

Ultimately, system EBO targets should be set so that DLA's support for a system is in balance with the owning Service's support for the system. As we saw earlier, *if* 30 percent of demand for WSSP/USAF items is coming from USAF aircraft, then current DLA support is in balance with Air Force support: the same number of aircraft (13) are affected for every $1.0 million change in WSSP/USAF safety levels as D041 safety levels. This approach effectively ties DLA EBO targets to weapon-system-oriented availability targets but enables DLA to avoid having to build new, system-oriented availability models to compute safety levels.

Deciding whether DLA is in balance with its customers, however, requires point-of-use demand information. In the interim, DLA could use the same method we used in the F-16 experiment to set system EBO targets: compute system EBOs based on the current set of SAMMS safety levels for the items, and use the resulting number as the beta EBO target in a system calculation, keeping the usual SAMMS rules on lower and upper bounds for safety levels. The F-16 example suggests that

DLA could save money with this interim approach and simultaneously improve weapon system support.

SUMMARY OF RECOMMENDATIONS

In summary, the proposals for changing the way the WSSP works are for DLA to take the following actions:

For purposes of system VSL calculations, group items by weapon system/end item. Within system groups, account for item essentiality by distinguishing: grounding LRUs, mission-impairing items (both LRUs and repair parts), and nonessential items. Identify LRUs using the third-position value of the SMR code for item/weapon system combinations.

Work with the Services to obtain retail-level, point-of-use demand factors for WSSP items. Demand percentage by weapon system versus nonweapon system would be enough to determine whether overall DLA support is in balance with Service support – by enabling comparison of marginal aircraft-per-dollar ratios for DLA with those inherent in Service weapon system availability targets.

Set safety levels for common components by computing arrays of safety levels, and use weapon system group codes as the basis for assigning the final, single wholesale safety level for the item. When and if information on point-of-use demand by system becomes available under SIWSM, use point-of-use demand factors to adjust EBO values for common components when calculating safety levels to meet specific system EBO targets.

Begin now to address the organizational and budgeting questions that accompany setting WSSP safety levels by weapon system. If item management by the DLA Supply Centers is going to continue to be commodity-oriented (which makes sense given their procurement responsibilities), headquarters and the centers should form a group to develop a working plan for how WSSP safety levels will be set, including policy for system EBO targets and procedures for WSSP budget development and justification. The first step for such a group would be to perform the F-16 experiment on other systems, including Navy and Army systems, in addition to more Air Force systems.

CHAPTER 4

THE PROBLEM OF UNEXPECTED BACKORDERS

We have made the connection between DLA supply operations and readiness in the Air Force by looking at expected backorders – EBOs. Starting with the safety levels for a set of items, we have predicted – using mathematical inventory models – what the average number of outstanding unit backorders will be over time (both at wholesale and retail) and what that means in terms of high-priority due-outs at bases and mission capability rates for aircraft. But not every backorder on the books exists necessarily because of the way a safety level has been set in the supply system. Some backorders are completely independent of stockage-level decisions. If nobody is manufacturing a bolt meeting certain shear tolerances, DLA supply managers can set stockage levels wherever they want. Backorders will continue to accumulate until the *procurement* problem of finding a suitable supplier is solved.

This chapter is about such *unexpected* backorders – the ones that supply managers cannot control through stockage – but that have just as much chance to affect readiness as EBOs, which supply managers can control with their levels.

ACTUAL OUTSTANDING UNIT BACKORDERS

For the 176,246 items in the study, at the end of March 1989, 23.6 million unit backorders existed at the wholesale level. To emphasize: we are talking here about *unit* backorders. Requisition backorders (i.e., backorder lines) – the ones DLA supply managers generally look at – were just under 200,000 at the end of March.

The number of outstanding unit backorders at any given time is a single observation. To obtain an empirical estimate of the EBO values that we calculate with inventory models, we would have to make several observations at different times and average them. For our WSSP/USAF items, we do have a second observation: At the end of June 1989, 20.3 million unit backorders existed. That suggests the March 1989 observation is not anomalous and that roughly 20 million outstanding unit backorders for demand-based WSSP/USAF items may well be the norm.

The problem is that with the safety levels in the file for the 176,246 items, along with the historical data on demand and demand variance, the inventory model we used – a basic, SAMMS-like inventory model – predicts unit EBOs of about 4.8 million. Something is wrong. Either the model is totally disconnected from the real world, the item data are wildly wrong, or a large number of the outstanding backorders are *unexpected* backorders – that have nothing to do with stockage levels in the WSSP/USAF program.

The SAMMS inventory model is fundamentally a reasonable model. Like all inventory models, it assumes that demands in a leadtime will be distributed around some average and computes EBOs using the standard mathematics of probability theory.

The item data, from which the probability distributions in the model are built, are certainly not perfect. Research at DLA, LMI, RAND, and elsewhere has shown that demand rates and other item factors for military hardware items can be quite unstable over time, making the demand prediction problem very difficult. Nevertheless, it is hard to believe that there could be such large differences between historical behavior and current conditions.

But 23.6 million outstanding unit backorders is not a feasible observation if the average is supposed to be 4.8 million. Where did the additional 18.8 million backorders come from?

UNEXPECTED BACKORDERS

By checking the data base for items with large numbers of backorders in place at the end of March 1989, we found 3,410 items (2 percent of the total number of items) that accounted for 21.7 million (92 percent) of the total number of outstanding unit backorders. Do these items have some characteristic in common that might explain why they have so many backorders?

The record for each item in the data base included the due-in quantity as of the end of March 1989. Due-in quantities are unit quantities of supplies "scheduled to be received from vendors, repair facilities, assembly operations, interdepot transfers, and other sources" according to the *DLA Supply Operations Manual.* In other words, the due-in quantity for an item is the amount DLA has on order to replenish its wholesale stocks.

By dividing the due-in quantity for each item by its monthly demand rate, we can see how many months of demand the due-in quantity represents. We did that for the 3,410 items and found that due-in quantities on average represented *more than 64 months' worth of demand.* Put another way – in terms of order quantities – these items have an average due-in amount of more than seven order quantities. That means for a typical item, more than seven orders have been placed since the last time replenishment stocks were delivered.

It is possible that some of the 3,410 items have experienced demand spikes. That could cause multiple orders to be placed over a short time period. But those spikes would have to have been very large and would have to have occurred over a comparatively short span of time. If, instead of spiking over a brief interval, demand had been steadily increasing over time, SAMMS forecasting procedures would have begun to adjust demand forecasts upwards and order quantities would have risen – making it even harder for due-ins to be so large when expressed in terms of order quantities.

Rather than a change in demand, these extraordinarily large due-in quantities strongly suggest that these items have *supplier* problems. Each item is reaching its reorder point and orders are being placed, but, for some reason, stocks are not being delivered. If such is the case, most of the backorders for these items have nothing to do with – and cannot be solved by – stockage levels in SAMMS. Most of the backorders are "unexpected" in the sense described above. (If the reason for so many backorders is that leadtimes have stretched considerably, that is just another way of saying that supplier problems exist. If suppliers are not available or are not delivering, leadtimes do get longer.)

SUPPLY ADJUSTMENTS ARE NOT THE WHOLE STORY

In our earlier analysis, we saw how DLA's supply operations – specifically how DLA computes and sets safety levels – can affect Air Force readiness. Here we have seen that a large part of the outstanding-backorder "problem" for WSSP items may have very little to do with how stockage levels are set. What does that say about DLA's ability – in the way it sets stockage levels – to influence and control its effect on readiness?

First, of course, we have to recognize that the readiness effects of DLA stockage procedures are not reflected merely in outstanding backorder levels. All the times

backorders did *not* occur are also a function of where DLA has set its levels. [That's why we placed the word "problem" in quotes in the preceding paragraph.] The large numbers of aircraft and other end items in the Air Force that, most of the time, *are not* waiting for a DLA item are that way in part because of what DLA does at the wholesale level. Chapters 1 and 2 are about readiness effects on the margin, measured against the much larger, underlying baseline of DLA support.

Having said that, the existence of unexpected backorders shows, nevertheless, that DLA cannot expect to be able to completely control its contribution to readiness just by worrying about where and how to set stockage levels. In our F-16 experiment, for example, *expected* backorders went from 745,000 down to 550,000, when we changed the way we computed VSLs for the 19,845 items involved. But those same items had another 2.7 million *unexpected* backorders on the books at the end of March 1989, above the expected value of 745,000. Many of these additional backorders would be unaffected if DLA were to change the way it computes WSSP safety levels.

ATTACKING THE PROBLEM OF UNEXPECTED BACKORDERS

As a first step, DLA should develop a profile of the 3,410 items – describing the "What . . . Why . . . How . . . When . . . and Who?" – to see what other characteristics they may have in common and where opportunities exist to fix the problem. Most of the items are managed at DISC, for example, although every Supply Center is represented. (DISC has 75.6 percent of the 3,410 items; DCSC, 9.4 percent; DGSC, 8.2 percent; and DESC, 6.8 percent.)

The fact that not many items are involved makes it possible to do more in-depth analysis if that becomes necessary. It may be possible to learn something by interviewing item managers, for example. That approach would make less sense (and might not even be feasible) if 100,000 items were involved.

Finally, DLA should keep in mind the implications for future supply analyses. If DLA undertakes development of new, general-purpose simulation tools, for example, it will be important to explore ways to include the fact of unexpected backorders. Otherwise, such efforts may miss what appears to be a large and unavoidable fact of life about DLA operations and performance.

APPENDIX A

DESCRIPTION OF THE DATA BASE

This appendix profiles the 176,246 items that served as the data base for the study. To be included, an item had to:

- Be in the Defense Logistics Agency (DLA) Weapon System Support Program (WSSP) (at Air Force request)
- Have a DLA item category code (ICC) of "1" [i.e., be a demand-based item in the Standard Automated Materiel Management System (SAMMS)]
- Have a DLA supply status code (SSC) of "1", "4", "7", "8", "9", or "A" (i.e., be a stocked item at DLA).

For an item to be in the WSSP, a Service must ask that it be placed in the program and must identify the weapon system or systems to which it applies. We looked at items placed by the Air Force because they would be the ones (presumably) with the greatest potential to affect Air Force readiness. The Air Force, however, uses some WSSP items that are in the program at the request of another Service. We did not include such items in the data base primarily because of difficulty in obtaining source, maintenance, and recoverability (SMR) data for them. In an initial look at about 240,000 demand-based WSSP items showing the Air Force as a user – but without regard to whether the Air Force had placed the item in the WSSP – only about 55 percent found matches [on national stock number (NSN)] in the Air Force D049 data used to obtain SMR information. (The Air Force's D049 Master Material Support Record system provides "bill of material" information on the parts that depot-level reparables, various equipment items, and weapon systems may need when they go to depot repair.)

Item Category Code "1" items are demand-based items: That means in SAMMS the safety levels for such items are determined by inventory calculations that are based in part on historical demand rates and variances.

"Non-demand-based" items are: ICC "2" (numeric stockage objective – NSO) items, ICC "B" (insurance) items, and ICC "P" (program-oriented) items. ICC "2" and "B" items are low-demand items whose stockage levels are determined by policy rules

rather than demand-based calculations. ICC "P" items are items whose stockage requirements are determined by the size of future programs (e.g., projected troop strength and induction levels) rather than historical demand. Virtually all program-oriented items are apparel items (uniforms, boots, coats, etc.) managed by the Clothing and Textiles Directorate at DLA's Defense Personnel Support Center (DPSC) in Philadelphia. Very few DLA hardware items are program-oriented.

About 188,000 non-demand-based items are carried in the WSSP/U.S. Air Force (USAF) program. They were not included in the data base because they account for less than 0.5 percent of annual unit demand and only about 1 percent of total outstanding unit backorders. Such items can cause isolated incidents, of course, and they may get a lot of attention when that happens. Because they are low-demand by nature, however, non-demand-based items cannot and do not have systemic, across-the-board effects on readiness (which is what we are interested in).

Supply status code "1" items are DLA-stocked items. SSC "4" items are Military Assistance Program items. SSC "7" items are stocked for overseas use only (CONUS use is to be supported by local purchase). SSC "8" items are stocked for issue as Government-furnished materiel. SSC "9" items are semiactive items. SSC "A" items are items originally classified as NSO or insurance when first brought into DLA's inventory. (Subsequent demand can cause such an item to become a demand-based, ICC "1" item, but the SSC is not always updated in SAMMS.)

Supply status codes *excluded* from the data base were SSC "2," non-stocked, local purchase items; SSC "3," nonstocked but centrally procured items; SSC "5," nonstocked, reference-only items; SSC "6," terminal items to be issued until stocks are exhausted; and SSC "0," items with no supply status at DLA.

Item records for each of the 176,246-item data base were provided by DLA's Operations Research Office (DLA-DORO) in Richmond, Virginia, by arrangement through the Operations Research and Economic Analysis Office (DLA-LO) at DLA Headquarters in Alexandria, Virginia. DORO drew data from the DLA Item Data Bank (DIDB), reflecting extractions from SAMMS files current as of the end of March 1989.

A record description for the DORO file, with brief definitions for each data element, appears after the next section, which contains various profiles of the data base. Following the record description is a listing of the 206 Air Force weapon

systems and end items supported in the WSSP/USAF program (as of 30 January 1989). Inconsistencies and other problems in the data base are described in the final section of the appendix.

ITEM PROFILES

The average price of each of the 176,246 items in the data base is $35.92. Prices range from a maximum of $19,327.44 to a minimum of $0.01. The total value of item safety levels for the data base is $250,735,012. The total value of reorder point quantities is $1,121,950,144.

Table A-1 stratifies the 176,246 items by number of Service-level users. In the record for each item, a "1" in the user code data element for a Service indicates that Service is registered as a user in the Defense Integrated Data System (DIDS) catalog; a "0" indicates the Service is not registered as a user.

TABLE A-1

USER BREAKOUT

User codes					Number of items	% of total items	% of annual demand frequency (6,053,450)	% of annual demand quantity (406,035,716)
Air Force	Navy	Army	Marines	Other				
1	0	0	0	0	41,003	23	6	3
1	1	0	0	0	36,023	20	9	10
1	1	1	0	0	28,767	16	10	10
1	1	1	1	0	24,775	14	20	13
1	1	1	1	1	20,923	12	44	51
– *Other Combinations* –					24,755	15	11	13

The total annual demand frequency of 6,053,450 requisitions reflects the total number of recurring-demand-type requisitions DLA received for demand-based WSSP/USAF items over the course of the year ending 31 March 1989. It is the sum of the "annual recurring demand frequency" data element across all 176,246 items. The total annual demand quantity of 406,035,716 reflects the total number of *units* demanded (as opposed to requisitions received) over the course of the year. It is the

sum of the "annual recurring demand quantity" data element. To get an estimate of the *daily* demand rate across the 176,246 items in the study, we can divide 406,035,716 units by 365 days, to obtain a daily demand rate of 1,112,426 units per day.

Table A-2 stratifies the data base by DLA Supply Center. It shows how many items each Center manages and the associated backorder lines and backorder quantities outstanding for those items at the end of March 1989.

TABLE A-2

SUPPLY CENTER BREAKOUT

Supply Center	Items	% of total items	Backorders					
			Lines	% of lines	% of annual demand frequency	Units	% of units	% of annual demand quantity
DISC	79,817	45	121,498	62	41	19,364,807	82	68
DESC	54,023	31	23,771	12	24	790,920	3	8
DCSC	21,579	12	26,511	14	18	1,449,831	6	7
DGSC	20,827	12	23,853	12	17	2,018,005	9	17
			195,633			23,623,563		

Note: DISC = Defense Industrial Supply Center; DESC = Defense Electronics Supply Center; DCSC = Defense Construction Supply Center; DGSC = Defense General Supply Center

The "% demand frequency" and "% demand quantity" columns in Table A-2 show that although it has less than half (45 percent) of the items, the Defense Industrial Supply Center in Philadelphia experiences well more than half of the total annual requisition and unit demand in the WSSP/USAF program. That explains in part why DISC's share of outstanding backorders (both lines and units) is so large. The other reason is that DISC is responsible for three quarters of the 3,410 items discussed in Chapter 4 of the main text for which extraordinarily large backorders are outstanding and (by way of likely explanation) even larger "due-in" quantities are on-order (see Chapter 4).

The total of 23,623,563 unit backorders (outstanding at the end of March 1989) was obtained by adding the "backorder quantity" data element for all 176,246 items

in the data base. If we divide that number by the daily demand rate of 1,112,426 units per day, we get an estimate of 21.2 days as the average depot delay that DLA imposes on its retail customers for items in the USAF/WSSP program.[1] That number is important because it leads to the estimate that 5 days would be added to the order-and-shipping times (OSTs) experienced by bases if DLA were to cut USAF/WSSP safety levels by 20 percent. A 20 percent reduction in wholesale-level USAF/WSSP safely levels causes a 23.6 percent increase in unit expected backorders (EBOs), which translates into an increase of 5 days (0.236 × 21.2 days) in average depot delay imposed on Air Force bases for USAF/WSSP items.

If, instead of 23.6, we use 4.8 million backorders as the unit EBO figure (because 18.8 of the 23.6 million backorders are "unexpected" and, therefore, do not reflect what the *supply* system is doing), we get an average depot delay of 4.36 days and an increase in base OSTs of about 1 day rather than 5 days (0.236 × 4.36 days = 1.03 days). In rough terms, that increase would translate into an 80 percent reduction in both the aircraft and high-priority due-out effects described in Chapter 2. That would mean a $50 million, 20 percent across-the-board reduction in WSSP/USAF safety levels would render only 6 to 8 more aircraft not mission capable–supply (NMCS) or partially mission capable–supply (PMCS) out of the available Air Force fleet of 7,800, and would increase the number of outstanding, high-priority due-outs at a typical Air Force base by a dozen or less. In other words, we would conclude that Air Force readiness is not particularly sensitive to changes in DLA safety levels, even if those changes are substantial.

Indeed, *if* more than 90 percent of DLA's outstanding, wholesale-level backorders have absolutely nothing to do with how DLA sets safety levels (but instead are due to various kinds of supplier problems not amenable to "inventory" solutions), such a conclusion would be unavoidable. That leads to the not entirely unreasonable proposition that DLA's contract and procurement practices have more potential influence on readiness than do the Agency's internal stockage policies. The

[1]Here we are using the basic relationship: EBO = DDR × NFR × AVBOD (discussed in Chapter 1 of the main text), where DDR is the daily demand rate, NFR is the nonfill rate (1-supply availability), and AVBOD is the average backorder duration when one occurs. From Military Supply and Transportation Evaluation Procedures (MILSTEP) reports for the first three quarters of FY89, the supply availability rate at DLA's four hardware Supply Centers for *all* items (not just WSSP/USAF items) was about 89 percent, making the nonfill rate about 11 percent. With an EBO figure of 23.6 million unit backorders, that yields a backorder duration of about 190 days on average. The overall average depot delay figure of 21.2 days reflects the combined average of zero days of delay when demands are filled and 190 days of delay on average when they are not.

problem, of course, is that it is hard to know when it is the supply system's "fault" that a backorder exists and when it is something beyond the supply system's control. The prudent course for DLA managers is act as though the projected effects in Chapter 2 are not overstated and seek ways to operate their entire system – supply and procurement – more efficiently under that assumption.

Table A-3 stratifies the data base by Federal Supply Group (FSG). (The first two digits in an item's NSN identify the FSG to which the item belongs.) Understanding *what* kinds of items we are actually talking about in the WSSP/USAF program is important to an understanding of the potential readiness effects, and Table A-3 provides some help in that regard. [Although the names of items can sometimes give a clue as to whether the item might be a line replaceable unit (LRU), or essential, or used only on aircraft, the large number of distinct item names in the data base prevented a useful "sort." The 176,246 items in the data base have 10,970 distinct names.]

TABLE A-3

FEDERAL SUPPLY GROUP BREAKOUT

FSG	Items	% of total items	Unit backorders	% of unit backorders	% of annual demand quantity
53 Hardware & Abrasives	70,383	40	12,600,100	53.0	48.0
59 Electrical & Electronic Equipment Components	59,073	34	1,133,611	5.0	15.0
47 Pipe, Tubing, Hose & Fittings	11,017	6	725,210	3.0	5.0
31 Bearings	5,836	3	157,560	0.7	0.7
61 Electric Wire, and Power and Distribution Equipment	4,375	2	5,927,492	25.0	18.0
62 Lighting Fixtures and Lamps	3,822	2	711,500	3.0	3.0
96 Ores, Minerals, and Their Primary Products	4	0	681,873	3.0	0.2
(44 other FSGs)	21,736	13	1,686,217	7.0	10.0

The preponderance of hardware and abrasive items helps explain how it is that DISC plays such an important role in the USAF/WSSP program. More than 69,000 (98 percent) of the 70,383 hardware and abrasive items in the data base are managed at DISC. Of the 70,383 FSG "53" items, 41,227 (59 percent) have Federal Supply Classes (first four digits of the NSN) identifying them as screws, bolts, studs, nuts, washers, nails, keys, pins, or rivets. (Federal Supply Classes: 5305, 5306, 5307, 5310, 5315, and 5320.)

FSG "53" items account for just over 48 percent of the total annual recurring demand quantity for all demand-based WSSP/USAF items. That partly explains how it is possible, as Table A-3 shows, that 53 percent of the total number of outstanding unit backorders in the WSSP/USAF program at the end of March 1989 were for hardware and abrasive items.

Table A-4 stratifies the data base by number of weapon systems to which the item applies. As the table shows, of the 176,246 items in the study, 50,566 apply to only one weapon system. That weapon system is necessarily an Air Force weapon system, because we are looking at items that the Air Force placed in the WSSP program. (A complete listing of the 206 Air Force weapon systems and end items supported in the WSSP/USAF program appears later.)

If we compare Table A-4 with Table A-1, the question arises, "If 50,566 items apply to single weapon systems in the Air Force, how can the Air Force be the single user for only 41,003 items?" The answer is that 9,563 items have Service user codes of "1" for at least one other Service besides the Air Force, but since that other Service (or Services) has not identified the items to any of its weapon systems, only the Air Force weapon system shows up as an applicable system. User codes are simply "passed" information based on DIDS catalog listings – they do not define which Service placed the item in the WSSP.

Conversely, not all the items (the remaining 71 percent) with multiple-weapon-system applications apply only to Air Force systems. Many items in the WSSP/USAF program are identified as having application to Army, Navy, and Marine Corps weapon systems, too. That is why many items apply to more than 206 systems, even though there are only 206 Air Force systems supported in the WSSP/USAF program (as of 30 January 1989).

TABLE A-4

NUMBER-OF-WEAPON-SYSTEMS BREAKOUT

# weapon systems	Items	% of total items	Unit backorders	% of unit backorders	% of annual demand quantity
1	50,566	29	2,562,265	11	7
2	26,939	15	1,891,551	8	5
3	17,055	10	1,998,269	8	5
4	11,908	7	1,307,660	6	4
5	8,935	5	2,717,155	12	4
• • •					
352	1	0	1,309	0.01	0.01
• • •					
431	1	0	0	0	0

As shown in Table A-4, the 50,566 items that apply to single Air Force weapon systems account for 11 percent of the total unit backorders outstanding at the end of March 1989 and 7 percent of total annual recurring demand. Even though only 71 percent of the items in the WSSP/USAF program apply to more than one weapon system, those items account for 93 percent of annual demand and 89 percent of outstanding backorders.

Table A-5 stratifies the data base by weapon system indicator code (WSIC). WSICs are defined in Chapter 3 of the main text in the discussion of item essentiality. They are listed in Table A-5 in descending order of importance, Note, for example, that nonessential items on critical systems ("P" items) are ranked higher than essential items on less critical systems ("K" items). The "importance" ranking of WSICs appears in DLA Regulation 4140.38, Enclosure 3, and reflects a conscious decision on DLA's part to focus more on the importance of the supported systems than on item essentiality in deciding how to allocate constrained procurement dollars.

The distribution of outstanding unit backorders in Table A-5 is interesting in terms of what it says about the difficulty in using item essentiality schemes, like

TABLE A-5

WEAPON-SYSTEM-INDICATOR-CODE BREAKOUT

WSIC	Items	% of total items	Unit backorders	% of unit backorders	DISC's portion	% of annual demand quantity
F	59,565	34	12,833,349	54	79	66
G	33,352	19	4,889,882	21	86	13
H	20,656	12	1,365,934	6	89	6
J	7,863	4	1,241,750	5	87	4
P	15,370	9	1,435,652	6	94	5
R	14,040	8	1,008,615	4	91	3
K, M, S	25,400	14	848,381	4	55	3

WSICs, to help provide support where it is most important. The "F" items, for example, which supposedly are absolutely essential to the most critical weapon systems, represent only 34 percent of the items, but they account for more than half of the outstanding unit backorders in the WSSP/USAF program.

To be sure, "F" items account for 66 percent of total demand, so it looks as though they are being given some useful emphasis. If all items were being treated equally, one might expect that the share of outstanding backorders for a group of items would match the group's share of annual demand – e.g., "F" items would have 66 percent of the outstanding backorders, rather than 54 percent. But when we examine the "G" items, this hypothesis breaks down. "G" items are supposedly essential to critical systems, but they account for a *greater* percentage of outstanding backorders (21 percent) than one would expect from their annual demand percentage (13 percent). Since "G" items are second only to "F" items in importance, it might make more sense to try to lower their backorder percentage to something below 13 percent, even if that meant allowing "F" items to have a few more backorders (but still less than 66 percent).

To do that, DLA could assemble "F" items and "G" items into separate groups and compute safety levels based on different EBO targets for each group (the approach essentially recommended in the main text in Chapter 3), or it could

experiment with different "weights" for "F" and "G" items in the current SAMMS safety-level formulas until EBOs for the two kinds of items were in the desired balance. The unwieldiness of the latter approach captures precisely the difficulties inherent in the use of item weighting schemes for computing safety levels.

The DISC percentages in Table A-5 show what portion of the various classes of items are managed at DISC. DISC is responsible for 79 percent (47,056 items) of the 59,565 "F" items in the data base, for example.

Table A-6 stratifies the data base by Supply Center, and within Supply Center, by the value in the third position of the SMR code. For an item/weapon system combination, the third position of the SMR code tells the lowest level of maintenance ("O" for organizational, "F" for field or intermediate, and "D" for depot) authorized to remove and replace the item from the weapon system. In the Air Force D049 data system (the source for SMR information), a given NSN may appear many times depending on how many different applications it has to different weapon systems, end items, and reparable items subject to depot repair. In each such occurrence, either an "O", "F", or "D" will appear in the third position of the six-position SMR code. Table A-6 gives the various counts for the number of times the different possible values appeared in the D049 records. The percentages in the SMR portion of the table should be read *horizontally*, so that for the 79,817 DISC items, for example, 46 percent of the applicable D049 records showed an "O", 34 percent showed an "F", and 20 percent showed a "D".

TABLE A-6

SMR CODE BREAKOUT

Supply center	Items	% of total items	3rd position SMR code count					
			O	%	F	%	D	%
DISC	79,817	45	342,600	46	250,000	34	152,000	20
DESC	54,023	31	166,200	27	217,600	35	242,300	39
DCSC	21,579	12	35,600	57	22,900	37	4,200	7
DGSC	20,827	12	39,100	39	38,300	38	23,000	23

The point of Table A-6 is to provide an indication of the extent to which DLA-managed consumables apply as LRUs as opposed to being repair parts for other components. In the Air Force D049 records for DISC items, for example, 46 percent of the time DISC items apply as LRUs (because O-level "line" maintenance is authorized to remove and replace the item), and 54 percent of the time they apply as repair parts used in intermediate- and depot-level repair.

Individual items may be LRUs in one application and repair parts in another. Only a relatively small number of items were always repair parts or always LRUs. Table A-7 describes the "pure" repair parts in the data base – items that had no O-level removal indicated anywhere in the Air Force D049 data.

The items in Table A-7 have been grouped by item essentiality code to illustrate an important missing ingredient in existing essentiality schemes. The essentiality coding of "1" for the 28,333 parts in the first row in no way takes into account the stock levels already in the system for the components that those parts repair. Some of those components may be in long supply, for example.

TABLE A-7

PURE REPAIR PARTS

Item essentiality	WSIC	Number of items and (%) of 176,246	% of unit backorders	% of annual demand quantity
1	F, G, K	28,333 (16)	16	13
5, 6, or 7	H, J, M	9,980 (6)	2	3
3 or blank	P, R, S	9,404 (5)	3	2

Building up stock levels of repair parts for reparables in long supply is inefficient. The point of "indentured" inventory models – called for under the SIWSM concept – is to recognize that tradeoffs can be made in stock levels between repair parts and the things they repair. Current item essentiality schemes do not offer a way to make this tradeoff, which (based on experience with the Aircraft Availability Model) offers opportunities for substantial savings in inventory investment for given levels of performance.

For DLA, distinguishing between consumable LRUs and consumable repair parts in the calculation of WSSP safety-level requirements (as recommended in Chapter 3) would be a way for the Agency to get some of the benefits of an indentured calculation, without having to construct detailed, indentured application files for every item. DLA would simply choose smaller EBO targets for the repair parts in a system, in recognition of the fact that the Services have spares in their systems for the items that the parts repair.

Table A-8 describes the "pure" LRUs in the data base – items that had *only* O-level removals indicated in the Air Force D049 data.

TABLE A-8

PURE LRUs

LRUs	WSIC (grouped by item essentiality)	% of 176,246 items	% of unit backorders	% of annual demand quantity
Grounding	F, G, K	8	3	8
Impairing	H, J, M	2	1	1
Support	P, R, S	3	2	1

As in the previous table, the items in Table A-8 are grouped by item essentiality. The "support" LRUs in the third row are items that are LRUs in all their applications but have no effect at all on the operability of their parent systems. In discussing this table and the previous one, we have acted as though the WSIC information for each item in the data base were valid and correct. The discussion in Chapter 3 of item essentiality, however, suggests that there may be problems in the way WSICs are being assigned. If the WSIC codes were valid for the 8 percent of the items that are LRUs in all their applications and are capable of "grounding" at least one of their parent systems, DLA might well want to provide extra support for those items – because backorders for consumable LRUs have greater potential readiness effects than do backorders for repair parts.

All the things said so far about SMR information in the data base are based on the SMR data that could actually be obtained. Of the 176,246 items in the data base,

we either did not find a match on NSN in the Air Force D049 records for 63,440 items (36 percent) or the D049 record was blank. *Half* (31,162) the items with missing SMR information are in the three most important "F", "G", and "H" WSIC categories (see Table A-9).

TABLE A-9

MISSING SMR DATA

WSIC	Number of items missing SMR data	% of total items in WSIC category missing SMR data
F	12,437	21
G	11,190	34
H	7,535	36
	31,162	

The percentages in Table A-9 show what portion of the records in each of the three WSIC categories were missing SMR information. For example, the 12,347 "F" items that were missing SMR information represent 21 percent of the total number of 59,565 "F" items in the study.

If DLA begins to use SMR information, it will need to monitor Air Force efforts to keep data in the D049 "Master Materiel Support System" up to date and accurate. Air Force experience with the D049 system (in the Requirements Data Bank project, for example, which is aimed at modernizing requirements and execution systems for reparable spares) has shown that the system has *not* been well maintained. Both Air Force and DLA efforts to use D049 SMR information within their respective requirements systems will require improved quality and accuracy in the D049 data.

RECORD DESCRIPTION

Table A-10 is a record description for the records provided by DLA-DORO for each of the 176,246 WSSP/USAF items in the data base. Individual data elements contain values that were current in SAMMS on or about the end of March 1989. The field names on the left were used as variable names in the computer models developed for the analysis. (Appendix B contains program listings for the models.)

TABLE A-10

DORO TAPE RECORD DESCRIPTION

Data element	Definition
COMM	Commodity
NSN	National Stock Number
FSG	Federal Supply Group (POS 1 – 2 of NSN)
FSC	Federal Supply Class (POS 1 – 4 of NSN)
FMC	Family Member Code
FMN	Family Member Number
NAME	Item Name
ORC	Output Routing Code
UOI	Unit of Issue
SSC	Supply Status Code
USERA	User Code Army
USERAF	User Code Air Force
USERM	User Code Marine
USERN	User Code Navy
USERO	User Code Other
PRICE	Unit Price in Dollars and Cents/100
BKLN	Backorder Lines
DILN	Due-In Lines
CCC	Catalog Change Code
DVC	Demand Value Code
FBC	Forecast Basis Code (1 = monthly, 2 = quarterly)
AGE	Age of Item Code
ICC	Item Category Code
IEC	Item Essentiality Code
MRC	Mobilization Reserve Code
PCC	Procurement Cycle Code
SLC	Safety Level Code
SLEC	Safety Level Essentiality Code
TSC	Tracking Signal Code
VIPC	Very Important Program Code
WSIC	Weapon System Indicator Code
WSINTC	Weapon System Interest Code
ALPHA	Alpha Factor/100
TSCNT	Tracking Signal Counter

TABLE A-10

DORO TAPE RECORD DESCRIPTION (Continued)

Data element	Definition
ALT	Administrative Lead Time Days
PLT	Procurement Production Lead Time Days
OLM	Operating Level Months
PCM	Procurement Cycle Months
SLM	Safety Level Months/10
MGTDT	Management Assume Date
LBDT	Last Buy Date
LDDT	Last Disposal Date
LDMDDT	Last Demand Date
ANDP	Applicable Nonrecurring Demand Percentage
ARQ	Additional Retention Quantity
AVRQ	Average Requisition Quantity
BKQTY	Backorder Quantity
DIQTY	Due In Quantity
DSQ	Double Smooth Quantity/10
IAQ	Issuable Asset Quantity
MRQ	Maximum Release Quantity
MADQ	Mean Absolute Deviation Quantity/10
MPQ	Minimum Procurement Quantity
NSOQ	Numeric Stockage Objective Quantity
QFD	Quarterly Forecasted Demand
QFDN	Quarterly Forecasted Demand New
QFR	Quarterly Forecasted Returns
RPQ	Reorder Point Quantity
SLQ	Safety Level Quantity
SSQ	Single Smooth Quantity/10
OWRMR	Other War Reserve Material Requirements Quantity
OWRMRP	Other War Reserve Material Requirements Protectable Quantity
ADQ	Annual Demand Quantity
ADF	Annual Demand Frequency
ANDQ	Annual Nonrecurring Demand Quantity
ANDF	Annual Nonrecurring Demand Frequency
ARDQ	Annual Recurring Demand Quantity
ARDF	Annual Recurring Demand Frequency

TABLE A-10

DORO TAPE RECORD DESCRIPTION (Continued)

Data element	Definition
ARTNQ	Annual Return Quantity
ARTNF	Annual Return Frequency
NDQ1	Nonrecurring Demand Quantity Quarter 1 (Current)
RDQ1	Recurring Demand Quantity Quarter 1 (Current)
RDQ2	Recurring Demand Quantity Quarter 2 (Previous)
RDQ3	Recurring Demand Quantity Quarter 3 (Previous)
RDQ4	Recurring Demand Quantity Quarter 4 (Previous)
RDF1	Recurring Demand Frequency Quarter 1 (Current)
RDF2	Recurring Demand Frequency Quarter 2 (Previous)
RDF3	Recurring Demand Frequency Quarter 3 (Previous)
RDF4	Recurring Demand Frequency Quarter 4 (Previous)
NWS	Number of Weapon Systems
WSC	Weapon System Codes (First 50)
OCNT	"O" Count
FCNT	"F" Count
DCNT	"D" Count

SUPPORTED SYSTEMS IN THE WSSP/USAF PROGRAM

Table A-11 lists all the Air Force weapon systems and end items registered in the WSSP/USAF program as of 30 January 1989.

TABLE A-11

AIR FORCE WEAPON SYSTEMS IN THE WEAPON SYSTEM SUPPORT PROGRAM

Weapon system
485L TACS
A/S32R-11 Refueling Truck
AFSATCOM Type 12 Terminal (AN/TSC-88)
AGMC/A-10
AGMC/A-7

TABLE A-11

AIR FORCE WEAPON SYSTEMS IN THE WEAPON SYSTEM SUPPORT PROGRAM (Continued)

Weapon system
AGMC/B-1
AGMC/B-52
AGMC/C-135
AGMC/C-141
AGMC/F-111
AGMC/F-15
AGMC/F-16
AGMC/F-4
AGMC/F-5
AGMC/MINUTEMAN
AGMC/MX
AGMC/T-38
Air Combat Maneuvering Instrumentation (ACMI)
Aircraft, AWACS, E-3A
Aircraft, B-1B
Aircraft, C-18A, EC-18B
Aircraft, CORSAIR A-7D
Aircraft, DELTA DART F-106
Aircraft. EAGLE F-15
Aircraft, F-111
Aircraft, F-16
Aircraft, FREEDOM FIGHTER F-5
Aircraft, GALAXY C-5
Aircraft, HERCULES C-130
Aircraft, OV-10A
Aircraft, PHANTOM F-4
Aircraft, SOF (AC130A, AC130H, MC130H, EC130E)
Aircraft, STARLIFTER C-141
Aircraft, STRATOFORTRESS B-52
Aircraft, STRATOLIFTER C-135
Aircraft, T-33
Aircraft, T-39
Aircraft, THUNDERBOLT II, A-10
Aircraft, Trainer B-52

TABLE A-11

AIR FORCE WEAPON SYSTEMS IN THE WEAPON SYSTEM SUPPORT PROGRAM (Continued)

Weapon system
Aircraft, Trainer KC-135
Aircraft, Trainer T-4 & T-26
Aircraft, Airlifter C-17A
Aircraft, T-37
Aircraft, T-38
AN/FSQ-124A SATCOM Control Center
AN/TSC-85B(V)2, AN/TSC-93B(V)2 SATCOM Term
Ballistic Missile Early Warning System (BMEWS)
Bomb Unit, Guided (GBU-[illegible]5)
Bomb, Low Level Laser Guided (GBU-24)
Cargo System, 463L
COBRA DANE System FPS-108
Combined B-1B Systems (56F/BXF)
Combined B-52 Systems (04F/AYF/AZF)
Combined C-135 Systems (05F/AXF/AYF/AZF/BAF)
Combined C-5 Systems (11F/BRF)
Combined F-111 Systems (10F/BBF/BCF/BDF)
Combined F-16 Systems (26F/BUF/BVF)
Combined H-53 Systems (16F/BNF)
Combined SOF Systems (DUF/BNF)
Command Control and Communication System 427M
Communications Center (AN/TSC-107)
Communications Program, Combat Theater (TRI-TAC) 478T
Communications Terminal, Satellite (AN/TSC-100)
Communications Terminal, Satellite (AN/TSC-94)
Consolidated Space Operations Center
Defense Communications Meteorological (AN/TMQ-028, AN/TCC-76, AN/TPS-68, AN/TCC-77)
Defense Communications Radio (9 Systems)
Defense Communications Teletype (AN/ASR-02A, AN/MGC-02A, AN/TGC-20)
Defense Meteorological Satellite Program (DMSP)
Defense Specialized Program (DSP I)
Defense Specialized Program (DSP II)
Defense Specialized Program (DSP III)
Defense Support Program

TABLE A-11

AIR FORCE WEAPON SYSTEMS IN THE WEAPON SYSTEM SUPPORT PROGRAM (Continued)

Weapon system
Digital Subscriber Terminal (AN/TVC-0008V)
E-4B Airborne Command Post
Engine, Aircraft F-117, PW-100 (C-17A)
Engine, Aircraft F100-PW-100 (F-15A/B/C/D)
Engine, Aircraft F100-PW-200 (F-16A/B/C/D)
Engine, Aircraft F100-PW-229 (F15E, F16C/D)
Engine, Aircraft F101-GE-100 (B-1)
Engine, Aircraft F108 (CFM-56), (KC-135R)
Engine, Aircraft F110-GE-100 (F-16C/D)
Engine, Aircraft GE T-700 (UH-60A)
Engine, Aircraft J33-A-35 (T-33)
Engine, Aircraft J60-P-3 (T-39)
Engine, Aircraft J69-T-25 (T-37B)
Engine, Aircraft J75-P-17 (F-106A/B)
Engine, Aircraft J79-GE-15/17 (F-4C/D/E/F/G)
Engine, Aircraft J85-GE-21 (F-5E/F)
Engine, Aircraft J85-GE-5/13 (F-5A/B, T-38A)
Engine, Aircraft T400-CP-400 (H-1N)
Engine, Aircraft T53-L-13 (H-1D/H)
Engine, Aircraft T56-A-7/15 (C-130B/E/H/N/P)
Engine, Aircraft T56-A-9 (C-130A/D)
Engine, Aircraft T58-GE-1/3/5 (H-1F/P, H-3B/E)
Engine, Aircraft T64-GE-3/7 (H-53B/C/H, HH-53B)
Engine, Aircraft T76-G-10/12 (OV-10A)
Engine, Aircraft TF30-100 (F-111F)
Engine, Aircraft TF30-P-3/4/7/9 (F-111A/D/E)
Engine, Aircraft TF33-100 (F-111A/E)
Engine, Aircraft TF33-P-7 (C-141A/B)
Engine, Aircraft TF34-GE-100 (A-10)
Engine, Aircraft TF39-GE-1 (C-5A)
Engine, Aircraft TF41-A-1 (A-7)
Engine, Aircraft TF33-P-3/5/9/ (C/EC-135, B-52H)
Engine, Aircraft TF33-PW-102 (C-235E, EC-135H/K/P)
Engine, Aircraft, F100 PW220 (F-15C/D/E)

TABLE A-11

AIR FORCE WEAPON SYSTEMS IN THE WEAPON SYSTEM SUPPORT PROGRAM (Continued)

Weapon system
Engine, Aircraft – J57 All Models (C-135, EC-135, B-52)
Engine, Missile F112-WR-100 (Advanced Cruise Missile)
Frequency Management System (AN/TRQ-35)
Ground Based Electro-Optical Deep Space Surveillance System (GEODSS)
Helicopter, GREEN GIANT H-3
Helicopter, IROQUOIS UH-1
Helicopter, MH-608G PAVE HAWK
Helicopter, SOF/HH53 PAVE LOW
Helicopter, SUPER JOLLY H-53
High Speed Anti-Radiation Missile (HARM) AGM-88A
Intra-Theater Imagery Transmission System (ITTS)
Joint Surveillance System (JSS)/Region Opns. Contr. Center (ROCC)
Low Altitude Navigation & Targeting Infrared System (LANTIRN)
MILSTAR System
Missile, Advanced Medium Range Air to Air (AMRAAM)/AIM120A
Missile, MAVERICK AGM-65A
Missile, MINUTEMAN LGM-30
Missile, MX PEACEKEEPER
Missile, SRAM AGM-69A
Missile, Air Launch Cruise (ALCM) AGM-86B
Missile, Ground Launch Cruise (GLCM) BGM-109C
Missile, Strategic Air to Ground Strategic
NAVSTAR Global Positioning System
Over The Horizon Back Scanner (OTH-B) Program (AN/FPS-118)
Pave Phased Array Warning System (PAWS)
Pave Tack System
Power Conditioning Continuation Interface Equipment (PCCIE)
Precision-Location Strike System
Pumper, Mini
Radar Systems, Phase Array FPS-85
Regency Net System (AN/TRC-179(V), AN/FRC-180(V), AN/GRC-215)
Satellite Type 12 Terminal (AN/TSC-102)
Simulator, A-10
Simulator, AWACS, E-3A

TABLE A-11

AIR FORCE WEAPON SYSTEMS IN THE WEAPON SYSTEM SUPPORT PROGRAM (Continued)

Weapon system
Simulator, C-130
Simulator, C-135
Simulator, F-111
Simulator, F-15
Simulator, F-16
Simulator, F-4
Simulator, H-53
Simulator, T-45
Simulator, T-5
Simulator, Trainer C-141
Simulator, Trainer, C-5
Simulator, CH-3E
Simulators, SMK-87 & SMK-94
Simulators, T-50 & T-51
Single Chan Objective TAC Term (Scott) (TSC-124)
Small Intercontinental Ballistic Missile (ICBM)
Space Defense Operation Center-4 (SPADOC-4)
Support Equipment, A-10 Aircraft
Support Equipment, A-7 Aircraft
Support Equipment, B-1 Aircraft
Support Equipment, B-52 Aircraft
Support Equipment, C-130 Aircraft
Support Equipment, C-135 Aircraft
Support Equipment, C-141 Aircraft
Support Equipment, C-17A Aircraft
Support Equipment, C-5 Aircraft
Support Equipment, E-3A Aircraft
Support Equipment, E-4B
Support Equipment, F-106 Aircraft
Support Equipment, F-111 Aircraft
Support Equipment, F-15 Aircraft
Support Equipment, F-16 Aircraft
Support Equipment, F-4 Aircraft
Support Equipment, F-5 Aircraft

TABLE A-11

AIR FORCE WEAPON SYSTEMS IN THE WEAPON SYSTEM SUPPORT PROGRAM (Continued)

Weapon system
Support Equipment, H-1 Helicopter
Support Equipment, H-3 Helicopter
Support Equipment, H-53 Helicopter
Support Equipment, H-60 Helicopter
Support Equipment, MX PEACEKEEPER Missile
Support Equipment, OV-10A Aircraft
Support Equipment, Small ICBM
Support Equipment, T-37 Aircraft
Support Equipment, T-38 Aircraft
Tact. Info. Process & Interpretation System (TIPI) WS-428A
Target System, Aeriel Gunnery (AGTS)
Teletype, AN/UGC-129(V)-1
Teletype, AN/UGC-141(V)
TOW Tractor, Aircraft MB2
Tractor, Aircraft Towing, A/S32U-30
Tractor, Aircraft Towing, MB-4
Tractor, Flightline Towing
Traffic Contr. & Land. System (TRACALS) 404L
Trailer, Munitions Lift (MLT) MHU-173/E
Trainer, B1B Aircraft
Truck, Fire/Crash P-18
Truck, Fire/Crash P10
Truck, Fire/Crash P12
Truck, Fire/Crash P19
Truck, Fire/Crash P2
Truck, Fire/Crash P20
Truck, Fire/Crash P23
Truck, Fire/Crash P8
Truck, Fire/Crash P15
Vehicle, Aircraft Refueler R-14
Vehicle, Aircraft Refueler R-9
Total weapon systems = 206

INCONSISTENCIES IN THE DATA

Any large data base is likely to contain errors, inconsistencies, and bad data. The data base used for this study is no exception. The DLA Item Data Bank (DIDB), which served as the source for the wholesale-level data in the study, is itself a data base extracted from SAMMS, which supports day-to-day supply operations and requirements calculations at DLA.

The data themselves are insufficient to determine whether the problems described here are DIDB problems, SAMMS problems, or combinations thereof. None of these problems prevented the analysis from proceeding; all were "worked around" by exception processing in the models developed for the study. With the exception of mean absolute deviation in leadtime (MADLT), all the capitalized expressions that follow denote data elements in the raw data provided by DLA-DORO. The MADLT data element was computed from other raw data elements, following published DLA SAMMS documentation (the model listing in Appendix B shows how MADLT was computed).

Pipelines

The "demands-in-a-leadtime" pipeline is an important ingredient in requirements calculations for setting stockage levels. The data offered two ways to determine what these pipelines are:

$$\mathrm{RPQ} - \mathrm{OWRMRP} - \mathrm{SLQ}$$

or

$$(\mathrm{QFD}/91) \times (\mathrm{ALT} + \mathrm{PLT}).$$

The first way expresses the demands-in-a-leadtime pipeline as the remainder after subtracting "other war reserve materiel requirements protectable" (OWRMRP) and the safety level quantity (SLQ) from the reorder point quantity (RPQ). (In an inventory system, the reorder point is normally the sum of leadtime demand and safety level. DLA also includes OWRMRP, if any, in the reorder point.) The second way expresses the pipeline as the product of a daily demand rate [quarterly forecasted demands (QFD) divided by 91 days] times the leadtime in days [the sum of administrative leadtime (ALT) and production leadtime (PLT)].

Of the 176,246 records in the data base, 119,420 records (67.7 percent) have the property:

$$RPQ - OWRMRP - SLQ > (QFD/91) \times (ALT + PLT).$$

In 82,103 of these cases, the left-hand side is more that 10 units larger than the right-hand side. While special circumstances might explain reorder points occasionally larger than necessary, it is puzzling why so many reorder points appear to be larger than they "need" to be. It is possible that RPQ data and QFD data in the DIDB are out of phase in the sense that they are being drawn from SAMMS in a way that prevents them from being applicable at the same point in time. But if that were the case, one would not expect to see such a large bias in favor of larger-than-necessary reorder point quantities.

Backorders and Issuable Assets

A total of 17,696 records (10 percent of the data base) show outstanding backorders: 195,633 line backorders and 23,623,563 unit backorders. Of these, 11,293 records (65 percent) show issuable asset quantities (IAQ > 0). Of these latter records, 7,614 (67 percent) have the property that the IAQ is *greater* than the outstanding unit backorder quantity (IAQ > BKQTY), which means there would still be assets left after all backorders were filled.

Control levels allow item managers to hold assets and backorder routine replenishment requests to ensure the availability of stocks to cover higher priority demands. One possible explanation for these data, therefore, is that control levels are being overused. Pressures to fill high-priority demands can produce positive incentives to hold stocks. The problem, of course, is that failure to replenish retail stocks can lead to retail-level backorders, which, as we have seen, is where readiness effects actually occur. The use (and possible abuse) of control levels in wholesale DoD supply systems is a subject that merits further study.

Safety-Level Constraints

A common operating principle in DoD's wholesale supply systems – in conformance with DoD policy (DoD Instruction 4140.39) – is that the safety level for an item will not exceed the smaller of the item's leadtime demand or three standard deviations of leadtime demand. (A standard deviation computed by DLA is

1.25 × MADLT.) The purpose is to avoid the effects of extremes in the cost and demand data for items. SAMMS adheres to the policy (at least insofar as SAMMS program code reflects the operating rules described in SAMMS documentation).

In the data base, however, 11,390 records (6.4 percent) have SLQs greater than 3 × 1.25 × MADLT. This apparent breaking of the constraint on safety levels could be explained by safety-level quantities in the DIDB being out of phase with demand data. That would be a serious flaw in the DIDB data base, however, because it would mean *all* safety-level quantities are disconnected (analytically) from demand information in the data base. For the study, SLQ values were taken as the core indicator of where SAMMS "was" at the end of March 1989, rather than relying on demand data that may or may not have been properly up to date in the DIDB.

Procurement Cycles

Rather than giving the actual order quantity (Q) for each item, the DIDB gives the procurement cycle months (PCM), which tells the number of months of demand the order quantity represents.[2] Again following DoD policy, procurement cycles are supposed to be no less than 3 months' worth of demand, and SAMMS documentation indicates this policy is followed in SAMMS. In the data base, however, in 5,145 records (2.9 percent), PCM < 3. Among those records, PCM = 0 a total of 191 times.

Reorder Point Inconsistencies

By definition, the reorder point for an item is the sum of its leadtime demand plus safety level plus any special levels authorized to be part of the reorder point. In particular, therefore, the reorder point should always be greater than or equal to the safety level. In the data base, however, the safety level is greater than the reorder point (SLQ > RPQ) on 2,312 records (1.3 percent of the data base).

Standard Deviation in Leadtime Demand

After calculating MADLT values following SAMMS rules, there are 839 cases in the data base (0.4 percent of the records) in which MADLT is less than or equal to

[2]This usage is unfortunate because it mixes order quantity calculations with demand forecasting calculations. That mixture makes it impossible to tell whether problems are due to bad demand forecasts or flawed order quantity rules. As an aid to analysis, the DIDB should be modified to carry both the Q *and* the MADLT data elements that are computed and used in SAMMS.

zero (MADLT < 0). That would imply standard deviations in leadtime demand ($1.25 \times$ MADLT) that are either negative or zero, which does not make sense.

Zero Quarterly Forecasted Demand

The data base contains 216 records (0.1 percent of the data base) in which QFD equals 0. Even if recent demands have been zero, it is hard to understand how any demand-based item could have zero forecasted demand.

RECOMMENDATIONS

Inconsistencies in SAMMS/DIDB data bases are sufficiently widespread to merit attention in DLA's systems modernization efforts. DLA should also address them as part of its move towards weapon-system-oriented supply management.

Inconsistencies such as those described above may be due to timing and phasing problems in the way extractions are made from SAMMS files to build the DIDB. Another possibility is that problems exist in DIDB extraction routines. Or, the SAMMS code itself may be flawed as a result of updating and maintenance actions that have been performed over the years.

Whatever their cause, data problems deserve attention. Item requirements and actual buys are affected by the data, and good, consistent data make for better analyses.

APPENDIX B

METHODS, MODELS, AND DATA

In addition to the wholesale-level data from the Defense Logistics Agency (DLA) (described in Appendix A), retail-level data from the Air Force played an important role in the analysis presented in the main text. This appendix provides more information about the retail data and how they were used.

After the discussion of retail data and methods, the final sections of the appendix contains program listings for the inventory models used in the analysis. Three models – all with the same underlying mathematics – were used:

- A Standard Automated Materiel Management System (SAMMS)-like model used to analyze how wholesale-level expected backorders (EBOs) would change if DLA were to uniformly change safety levels for the 176,246 demand-based items in the the Weapon System Support program (WSSP) for the U.S. Air Force (USAF)
- A retail-level model [one version for the contiguous United States (CONUS) bases and another for bases outside CONUS (OCONUS)] used to analyze how retail-level EBOs (due-outs) would change at 10 representative Air Force bases, if wholesale EBOs at DLA were to increase and cause 5 days of increased depot delay for every demand-based USAF/WSSP item stocked at the bases
- A "system" model used to analyze the changes in wholesale safety-level investment and EBOs for the collection of 19,845 demand-based, WSSP/USAF items with applications to the F-16 aircraft.

HIGH-PRIORITY DUE-OUTS FOR DLA ITEMS

A very important fact described in Chapter 1 of the main text is that at base supply points in the Air Force, 20 percent of all due-outs for DLA-managed items are high-priority (Priority Group 1 or 2) due-outs. High-priority due-outs are outstanding, retail-level backorders between base supply and using customers that are preventing or limiting the base from being able to perform its assigned missions. The 20 percent figure is important because it tells how many of the EBOs computed

with the retail-level inventory models are high-priority due-outs. The latter figure in the derivation of the rule of thumb and other results given in Chapter 2.

Table B-1 summarizes the 19 months' worth of Air Force "Due-Out Schedule – Supplies" data (from worldwide Air Force Supply Management Reports) upon which the 20 percent figure is based. The monthly values in the table represent the total number of "firm" (as opposed to "memo") due-outs that were outstanding at the end of each month at Air Force bases worldwide, from March 1988 to September 1989. ("Memo" due-outs are for information purposes and do not involve actual backorders.) The due-outs shown are due-outs to *all* types of base customers: weapon maintenance, communications maintenance, civil engineers, vehicle maintenance, and other maintenance organizations.

If we exclude the June 1989 data, we get the estimate that 17.4 percent (513,553/2,947,757 = 17.4 percent) of firm DLA due-outs are high priority. The 20 percent figure is a compromise between 17.4 percent and 21.8 percent.

A problem with the worldwide supply management reports is that not every retail-level supply point in the Air Force reports every month. The "# supply points reporting/# total" column in Table B-1 shows the number of host and satellite supply points that reported for the given month and compares it with the total number of sites that could have reported. Notice, for example, that more sites (387) reported in June 1989 than in any other month.[1]

The right-hand column in Table B-1 contains estimates of the total number of outstanding due-outs worldwide if *all* supply points had reported. The estimates were obtained by multiplying the due-out values that were reported (listed in the first column of the table) by the reciprocal of the "# supply points reporting/# total" ratio. (The official Air Force reports do not contain these adjusted estimates – we added them here.)

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[1]The larger number of reporting sites in June 1989 may explain, at least in part, why the figures for that month are so much larger than those for the other months. Also, the June 1989 figures, compared with those for the other months, suggest the disheartening possibility that supply points in the Air Force are experiencing large numbers of outstanding due-outs and, at the same time, routinely failing to report their M32 data to the Standard Systems Center for inclusion in the worldwide summaries. If that is the case, the Air Force should take steps to improve M32 reporting discipline. The M32 worldwide supply management reports are important and can be valuable in helping the Air Force to track supply performance in the field.

TABLE B-1

DUE-OUTS AT BASES FOR DLA-MANAGED ITEMS

Month	Total DLA due-outs	# high priority	% high priority	# supply points reporting/ # total	Estimated total due-outs all users
Mar 88	104,395	15,954	15.2	232/408	183,591
Apr 88	124,688	19,678	15.7	289/410	176,893
May 88	117,852	19,771	16.7	282/408	170,509
Jun 88	124,642	22,818	18.3	300/410	170,344
Jul 88	149,171	26,809	17.9	331/408	183,872
Aug 88	160,391	28,487	17.7	345/410	190,610
Sep 88	155,438	26,751	17.2	304/410	209,637
Oct 88	211,432	31,823	15.0	328/410	*264,290
Nov 88	209,453	32,318	15.4	338/408	*252,831
Dec 88	167,434	26,614	15.8	292/410	*235,096
Jan 89	173,[illegible]87	29,346	16.8	307/408	*231,094
Feb 89	135,913	20,932	15.4	232/410	*240,191
Mar 89	215,189	34,663	16.1	374/420	*241,656
Apr 89	226,652	37,185	16.4	360/420	*264,427
May 89	191,186	31,442	16.4	349/420	*230,081
Jun 89	388,056	214,979	55.0	387/420	*421,146
Jul 89	149,409	26,981	18.0	316/420	*198,582
Aug 89	168,682	35,328	20.9	318/420	*222,788
Sep 89	161,943	46,653	28.8	274/420	*248,234
	3,335,813	728,532	21.8	* Total =	3,050,416

In Chapter 2 of the main text, we said that for the 141 major installations in the Air Force, an empirical estimate of the average number of high-priority, in-place due-outs for DLA-managed items is 350 per base. That estimate is derived from the data in the last column of Table B-1 as follows: The average value of total due-outs worldwide for fiscal 1989 (the 12 months from October 1988 through September 1989) is 254,201 due-outs (3,050,416/12 = 254,201). If we exclude the June 1989 data and take the average over 11 months, we get 239,024 due-outs. Using a figure of 250,000 as a compromise, and dividing by 141, we get 1,773 due-outs

(250,000/141 = 1,773) as an estimate of the total number of outstanding due-outs – of all priority types – at a typical base. Multiplying 1,773 times the high-priority factor of 20 percent yields the estimate of 350 high-priority due-outs per base.

HIGH-PRIORITY DUE-OUTS: DLA-MANAGED VERSUS AFLC-MANAGED ITEMS

A second, very important fact described in Chapter 1 of the main text is that Air Force Logistics Command (AFLC)-managed items consistently account for two to three times as many of the outstanding, high-priority due-outs at Air Force bases as do DLA-managed items. We used this fact when we calculated what a 9.7 percent increase in high-priority due-outs for DLA-managed items would mean in terms of additional not mission capable–supply (NMCS) and partially mission capable–supply (PMCS) aircraft (see the argument at the end of Chapter 1, where we used the factors 0.25 – 0.33 to obtain the number of aircraft in NMCS or PMCS status for DLA parts).

Again, the worldwide "Due Out Schedule – Supplies" summaries are the source of our information. For each of the 19 months from March 1988 to September 1989, we compared the number of firm, high-priority due-outs for AFLC-managed items to those for DLA-managed items. Table B-2 contains the results.

TABLE B-2

HIGH-PRIORITY DUE-OUTS: DLA VERSUS AFLC ITEMS

Monthly ratios for Priority Groups 1 & 2 due-outs AFLC items:DLA items			
Mar 88	2.7:1	Jan 89	2.5
Apr 88	2.8	Feb 89	2.5
May 88	2.8	Mar 89	2.6
Jun 88	3.1	Apr 89	2.5
Jul 88	2.9	May 89	2.6
Aug 88	3.2	Jun 89	2.1
Sep 88	3.3	Jul 89	2.4
Oct 88	2.9	Aug 89	2.2
Nov 88	2.9	Sep 89	2.1
Dec 88	2.8		

The due-outs being compared in Table B-2 are high-priority due-outs to the full range of base customers just as in Table B-1. Some of the due-outs for AFLC items are for AFLC-managed consumables in the Systems Support Division (SSD) of the Air Force Stock Fund. If and when DLA takes over responsibility for many of those items, the ratios in Table B-2 will move closer to 1.0. Unfortunately, there is no way to tell from the "Due Out Schedule – Supplies" reports what portion of the AFLC due-outs are for SSD items.

REPAIR-PART VERSUS LRU EFFECTS

As described in the "Due Out Schedule – Supplies" report, DLA consumables either are line replaceable units (LRUs) directly applicable to end items or are repair parts for other components, which apply to the end items. In their role as repair parts, consumables generally have less "leverage" on readiness, because spares for the components needing repair act as buffers, preventing end items from feeling the effects of repair-part shortages. The rule of thumb given in Chapter 2 of the main text quantifies how much less leverage consumables have when they apply as repair parts. It says the marginal effects (on aircraft) of changes in repair-part support are less than a tenth of the marginal effects associated with consumable LRUs. This section expands on the arguments and data underlying that finding.

Table 2-2 in Chapter 2 of the main text contains the key EBO effects that underlie the rule of thumb. Against a baseline of 1,800 high-priority due-outs at the 10 representative bases, it shows due-outs increase by 175 (9.7 percent), which serves as the basis for the argument that the number of NMCS and PMCS aircraft for DLA parts would increase 9.7 percent. All we know about the 175 new due-outs, however, is that they are high-priority ones. That means they could be for consumable LRUs that are keeping an end item waiting *directly* or they could be for consumable repair parts that are keeping an end item waiting *indirectly* because there are no spares for the component being repaired.

The question, therefore, is how many of the 175 new due-outs are of the latter type? To answer the question, we have to measure the "buffering effect" provided by spare reparables. We use the Aircraft Availability Model (AAM) to do that. It allows us to see how many due-outs for repair parts are able to become high-priority due-outs, after taking into account the spares levels for reparables that the Air Force plans to carry.

The basic flow of the argument is as follows: We start by using the AAM to determine the worldwide aircraft availability effects of increases in base and depot repair times – increases that occur as a result of increases in the average waiting times that maintenance customers experience when they order DLA repair parts from their retail supply points. (In subsequent sections, we describe how the increases – 0.5 days in base repair and 1.0 days in depot repair – were derived.) Next, we convert the AAM availability results into consumable LRU EBO quantities, using the mathematical relationship that exists between aircraft availability rates and LRU EBOs. Finally, we convert the worldwide LRU EBO effects into per-base effects and multiply by 10 to see how many of the 175 high-priority due-outs at the 10 representative bases are repair-part-type due-outs. The due-outs that are left among the 175 are, by a process of elimination, LRU-type due-outs.

Expanding on the first step, Table B-3 summarizes the availability effects of adding 0.5 days to base repair times and 1.0 days to depot repair times for reparable items in the Air Force. The effects assume reparable spares levels corresponding to AFLC's working aircraft availability targets, shown in the table.

The AAM run underlying the results in Table B-3 was performed on a March 1989 Air Force D041 data base, with availability results projected for FY91, a leadtime beyond the end of FY89. The 105 additional aircraft that become unavailable represent 1.43 percent of the projected FY91 primary aircraft inventory (PAI) fleet size of 7,318 for the 17 aircraft types shown.

We now convert the 1.43 percentage point change in the fleet availability rate into additional LRU EBOs using the following mathematical relationship (see Equation 2-1 in Chapter 2 of the main text):

$$0.8537 = \frac{0.8680}{e^{\Delta \text{ LRU EBOs}/7{,}318}},$$

where the left-hand value of 0.8537 is the "new" availability rate of 85.37 percent, obtained after subtracting 0.0143 from 0.8680. Solving for the change in LRU EBOs yields Δ LRU EBOs = 122. These additional LRU EBOs are outstanding, high-priority due-outs *for reparable components* that are needed by aircraft and that are in repair awaiting DLA parts.

TABLE B-3

AVAILABILITY EFFECTS OF INCREASES IN AVERAGE WAITING TIME IN BASE AND DEPOT REPAIR FOR DLA REPAIR PARTS

Aircraft types	Total FY91 fleet sizes (PAI)	Number of aircraft at AFLC target availability (target in parentheses)	Drop in aircraft availability rate (% points)	Additional unavailable aircraft awaiting repair of AWP components
Attack				
A-7	272	226 (83%)	1.0	3
A-10	566	509 (90%)	1.0	4
Bombers				
B-1	92	69 (75%)	3.0	3
B-52	186	167 (90%)	1.0	2
Airlift				
C-5	116	87 (75%)	3.0	3
C-130	606	545 (90%)	1.0	4
C-135	683	615 (90%)	1.0	6
C-141	250	220 (88%)	1.0	3
Fighters				
F-4	360	299 (83%)	1.0	4
F-15	851	706 (83%)	2.0	17
F-16	1,630	1,418 (87%)	2.0	39
F-111	261	214 (82%)	1.0	3
Helicopters				
H-1	74	55 (75%)	1.0	1
H-53	44	33 (75%)	2.0	1
H-60	54	40 (75%)	3.0	1
Trainers				
T-37	559	486 (87%)	1.0	6
T-38	714	664 (93%)	1.0	5
Totals	7,318	6,353 (= 86.8% of 7,318)		105

Note: AWP = awaiting parts

The final step is to convert the worldwide increase of 122 reparable LRU EBOs into a per-base increase. If we divide 122 by 141 (the number of major installations in the Air Force), we get an increase of 0.865 reparable LRU EBOs per base. If we divide 122 by 83 (the number of main bases listed in the 1989 Air Force Almanac as home to the aircraft types in Table B-3), we get an increase of 1.47 reparable LRU EBOs per base. Multiplying by 10, we obtain the estimate that among the 175 additional high-priority due-outs for DLA consumables at the 10 representative bases, somewhere between 9 and 15 are due-outs to repair lines and are keeping 9 to 15 broken reparables from being fixed and returned to waiting aircraft.

That means that of the 175 due-outs in total, 160 to 166 are consumable-LRU-type due-outs – roughly 10 to 20 times as many as are repair-part-type due-outs. We used a compromise multiple of 15 to derive the repair-part effects in the rule of thumb, which states that roughly 15 times as many aircraft are NMCS or PMCS for consumable LRUs as are NMCS or PMCS as a result of awaiting parts (AWP) conditions in repair lines.

AVERAGE RETAIL SUPPLY DELAY FOR DLA PARTS

Still to be explained is why an increase of 5 days in the average depot delay imposed by DLA on retail supply points in the Air Force translates into increases of 0.5 day in base repair times and 1.0 day in depot repair times for reparables. The 5-day increase is not passed through directly, of course, because retail-level stocks of DLA items at the bases and depots protect end users from directly feeling the effects of changes at the wholesale level.

The method for computing the increase in average retail waiting time is similar to that used to compute the increase in average wholesale delay. We first determine the current average delay or waiting time for DLA parts at retail supply points. That average waiting time is the product of the retail nonfill rate for DLA items times the average AWP time when a nonfill occurs. To obtain the *increase* in the average waiting time, we will multiply by the percentage increase in *retail* EBOs when 5 days of additional wholesale depot delay are added to order-and-shipping times (OSTs). This increase in average waiting time is spread uniformly across reparable repair pipelines, using a usage factor that measures the percentage of time that reparables require DLA parts.

In particular, the expression and values we use for calculating average retail waiting times and how they increase are

	PNP ×	NFR ×	AWP	× percentage increase in retail EBOs
Base:	0.58	0.32	17.3 days	(based on results of retail model
Depot:	0.88	0.23	17.3 days	runs for 10 representative bases),

where PNP (percent needing parts) is the usage factor that denotes the percentage of time that reparables entering repair ask for DLA-managed parts, NFR (nonfill rate) denotes the *retail-level* nonfill rate (1 – supply availability rate) for DLA items, and AWP (awaiting parts) denotes the average AWP time in repair when a reparable enters AWP status for a DLA part.

When they enter repair, some reparables do not require DLA parts. The increase in average waiting time computed with the above expression, however, is added to the repair time for *every* reparable component in the AAM data base. In the absence of data on which consumable repair parts apply to which reparables, the role of the PNP factor is to produce an increase in average waiting time for DLA parts that we can spread uniformly across *all* the reparable pipelines. This approach allows us to size repair-part effects without having to use item-specific, next-higher-assembly application data.

The PNP factor for reparables entering *base* repair, 0.58, was derived from "Customer Support Effectiveness" reports for the 12 months of FY89. Like the reports on due-outs, the Customer Support Effectiveness reports are part of the monthly, worldwide Supply Management Reports. The PNP factor was computed for each month by taking the ratio of the number of DLA items requested from retail supply by weapon maintenance organizations to the total number of items of all types (both reparables and consumables) requested from all sources of supply: AFLC, DLA, General Services Administration (GSA), local purchase, and other. Table B-4 contains the results.

What the data in Table B-4 show is that when weapon maintenance shops request parts from base supply, about 58 percent of the time they request DLA-managed items. We make the assumption that the 58 percent figure holds for reparables entering base repair.

The PNP factor for reparables entering *depot* repair (0.88) was derived from AFLC "Middle Management Reports" for July 1988 through December 1988. Each of

TABLE B-4

WEAPON MAINTENANCE ORGANIZATION DEMAND FOR DLA ITEMS AS A PERCENTAGE OF TOTAL DEMAND

Month	Unit demand for DLA items / Total unit demand (%)
Oct 88	61.3
Nov 88	58.7
Dec 88	58.4
Jan 89	58.0
Feb 89	57.1
Mar 89	57.9
Apr 89	58.5
May 89	60.7
Jun 89	58.5
Jul 89	56.8
Aug 89	56.6
Sep 89	55.0
Average	58.1

the Air Force's five Air Logistics Centers (ALCs) produces a monthly Middle Management Report to describe how the retail supply system at the center (the "D033" system) performed that month. The percentages in Table B-5 represent the ratio of unit demand for "base-computed" items (i.e., items from DLA, GSA, local purchase, and other sources) to total demand for all types of items: non-base-computed D041 reparables and D062 SSD consumables, as well as base-computed items.

The average value of the 18 entries in Table B-5 is 88 percent, which is the depot maintenance PNP factor. We assume the factor applies to DLA items alone, even though the data include some demands for base-computed items that may not be managed by DLA.

The 32 percent NFR factor at bases comes from "Issue Effectiveness" data for DLA parts in the Customer Support Effectiveness reports. Issue effectiveness rates measure the ratio of issues to issues plus backorders, without regard to whether the

TABLE B-5

DEPOT MAINTENANCE DEMAND FOR DLA PARTS
AS A PERCENTAGE OF TOTAL DEMAND

Month	USAF Air Logistics Centers (%)				
	Oklahoma City	Warner-Robins	San Antonio	Sacramento	Ogden
Jul 88	76.2	92.9	n/a	92.8	90.3
Aug 88	81.7	85.9	72.2	94.6	85.3
Sep 88	n/a	94.0	n/a	96.7	n/a
Oct 88	n/a	n/a	n/a	91.6	88.9
Nov 88	80.0	n/a	n/a	94.7	87.6
Dec 88	78.3	n/a	n/a	94.8	n/a

Note: n/a = data not available

items are stocked at base. (The fill rates for stocked items are measured by "stockage" effectiveness rates – also included in Customer Support Effectiveness reports.) Table B-6 contains the relevant data.

If we round the 67.8 percent issue effectiveness rate to 68 percent and subtract from 100 percent, we get a FY89 nonfill rate for DLA parts at Air Force bases worldwide of 32 percent.

The 23 percent NFR factor at depots is derived from data in the Middle Management Reports on unit issues, "wash posts," and backorders. (Wash posts are transactions posted in supply records that note the receipt and issue of items where there is no actual physical movement of the items through supply.) Table B-7 shows monthly fill rates for base-computed items at the Air Force's five ALCs from July 1988 through December 1988. The percentages represent the ratios of issues plus wash posts (in units) to the total of issues, wash posts, and backorders.

From the data in Table B-7, we assume a typical depot fill rate for DLA parts of 77 percent, which implies an NFR factor of 23 percent.

Finally, the estimate of 17.3 days as the average AWP time in base repair for DLA parts is based on "Repair Cycle Asset Control Reports" in the worldwide Supply Management Reports. The relevant data are reproduced in Table B-8. The data

TABLE B-6

RETAIL ISSUE EFFECTIVENESS RATES FOR DLA PARTS

Month	Units issued (millions)	Units backordered (millions)	Issue effectiveness (%)
Oct 88	3.9	1.5	71.9
Nov 88	3.4	1.4	71.3
Dec 88	2.6	1.1	70.1
Jan 89	3.4	1.5	70.0
Feb 89	1.9	0.9	67.8
Mar 89	3.8	1.7	69.6
Apr 89	3.7	2.2	62.5
May 89	3.6	1.7	68.0
Jun 89	3.6	1.7	67.3
Jul 89	2.6	1.2	67.9
Aug 89	3.1	1.8	63.3
Sep 89	1.9	1.1	64.2
	37.5	17.8	67.8

TABLE B-7

RETAIL FILL RATES AT AIR FORCE DEPOTS
FOR "BASE-COMPUTED" ITEMS

Month	USAF Air Logistics Centers (%)				
	Oklahoma City	Warner-Robins	San Antonio	Sacramento	Ogden
Jul 88	78	74	n/a	75	77
Aug 88	80	76	71	81	79
Sep 88	n/a	74	n/a	82	n/a
Oct 88	n/a	n/a	n/a	72	82
Nov 88	80	n/a	n/a	74	80
Dec 88	79	n/a	n/a	73	n/a

Note: n/a = data not available

reflect expendability, recoverability, repairability category (ERRC) code XD items that completed base repair in the given month *and* accumulated nonzero AWP time while they were in repair.

TABLE B-8

AWP TIMES FOR REPARABLE ITEMS IN BASE REPAIR IN THE AIR FORCE

Month	Number of ERRC Code XD items "repaired this station" that accumulated nonzero AWP time	AWP time accumulated (days)	Average AWP time (days)
Oct 88	14,901	423,758	28.4
Nov 88	24,542	786,220	32.0
Dec 88	14,371	396,371	27.6
Jan 89	12,952	412,454	31.8
Feb 89	7,435	310,388	41.7
Mar 89	17,566	256,865	14.6
Apr 89	15,919	94,784	5.9
May 89	14,642	71,014	4.8
Jun 89	16,667	68,591	4.1
Jul 89	9,981	44,194	4.4
Aug 89	12,817	47,357	3.7
Sep 89	8,791	30,860	3.5
	170,584	2,942,856	17.3

The Repair Cycle Asset Control Reports distinguish between items that had a maintenance priority code (MPC) of "4" or "7" when they were in base repair and those that had an MPC of "3", "C", "L", or "T".[2] The data in Table B-8 are for items in the latter category.

[2]From definitions given in the USAF Supply Manual (AFM 67-1, Volume II, Part Two), MPCs are assigned based on the stock position of the item at the base. MPC "3" refers to "AFLC Critical XD Items"; MPC "C" refers to "Major Command/Base Intensive Management Items"; MPC "L" refers to "Computed Supply Critical Items with Less than 10 Days of On-Hand Stock and a Due-Out Balance"; and MPC "T" refers to "Computed Supply Critical items with Less than 10 Days of On-Hand Stock and No Due-Out Balance." MPC "4" refers to "Items Required for Forecasted Base Requirements" and MPC "7" refers to "Items Excess to Base Requirements."

The 17.3-day average AWP time includes waiting time not just for DLA items but all types of repair parts – including other depot-level reparables (i.e., SRUs – shop replaceable units). Lacking further data, we have simply assumed it applies to base AWP times for DLA items. Actual DLA AWP values at bases may be smaller, if AWP times for reparable SRUs are greater than they are for consumables – as they may be. If that is the case, it would only reduce our projections of how DLA supply performance affects readiness in the field.

We have also assumed that the 17.3-day figure describes the average AWP time for DLA parts in the depot maintenance lines at the five ALCs in the Air Force. AWP information is not included in the monthly Middle Management Reports from the ALCs, so we simply used the figure derived for bases.

This concludes the description of the data and methods used to derive the current, or "baseline," values for average delay imposed by Air Force retail supply points on maintenance customers at bases and depots when they ask for DLA items. The next step is to find the percentage increase in retail EBOs in order to know how much additional delay occurs if base supply sites experience an increase in average wholesale delay when requisitioning from DLA, and they do not increase their stockage levels.

THE INCREASE IN RETAIL EBOs

To calculate the percentage increase in retail EBOs, we used a "retail" model that mimics the calculations in the Air Force's Standard Base Supply System (SBSS), which controls stockage levels at Air Force bases. We ran the model 10 times, using the retail-level data from each of the 10 representative bases for the DLA items that they stock. The results are contained in Table B-9. The "Days of AWP added" for each base are a function of the percentage increase in retail EBOs. They were obtained by multiplying the average retail supply delay at each base for DLA parts (PNP $\times$ NFR $\times$ AWP $= 0.58 \times 0.32 \times 17.3$ days $= 3.2$ days) times the percentage increase in EBOs at the base (computed with the model).

Table B-9 clearly shows that overseas bases do not experience as much additional AWP time in their repair lines as do CONUS bases. The reason, of course, is that overseas bases carry larger numbers of spares to cover their longer OST pipelines, so they are less sensitive to an increase in wholesale depot delay from DLA.

TABLE B-9

INCREASE IN EBOs AND CORRESPONDING INCREASE IN AVERAGE RETAIL SUPPLY DELAY IF 5 DAYS OF ADDITIONAL WHOLESALE DELAY ARE ADDED TO ORDER-AND-SHIPPING TIMES FOR DLA PARTS

CONUS (Baseline OST = 15 days)			OCONUS (Baseline OST = 60 days)		
Base	% increase in EBOs	Days of AWP added	Base	% increase in EBOs	Days of AWP added
Langley	15.6	0.50	Bitburg	5.0	0.16
England	25.5	0.82	Bentwaters	4.6	0.15
Little Rock	18.1	0.57	Kunsan	4.4	0.14
Minot	17.5	0.56	Clark	4.6	0.15
Randolph	26.0	0.83	Elmendorf	5.1	0.16

The value of 0.5 days that was added to the AAM base repair times for reparables is based on the results in Table B-9. The figure of 0.5 days is a compromise between CONUS and OCONUS effects.

The value of 1.0 days that was added to the depot repair times for reparables in the AAM was obtained by multiplying the average retail (D033) supply delay at ALCs for DLA parts ($PNP \times NFR \times AWP = 0.88 \times 0.23 \times 17.3$ days = 3.5 days) times an estimated percentage increase in retail EBOs at the depots of about 20 percent (3.5 days $\times$ 0.20 = 0.7 day) and rounding up to 1 day. The 20 percent increase in retail EBOs in the Air Force's D033 system is an estimate based on the assumption that D033 stockage levels are roughly equivalent (in terms of the protection they provide) to SBSS stockage levels at CONUS bases.

BASE-LEVEL DATA AND THE RETAIL MODEL

The Air Force Logistics Management Center (AFLMC) provided the retail-level data for the 10 representative bases in the analysis. Table B-10 contains the number of distinct national stock number (NSN) records from each base for DLA items, the number of matches (on NSN) against the 176,246 wholesale records from DLA, and the number of matches against the 98,472-item subset that showed an application to at least one of the 17 aircraft types in the AAM.

TABLE B-10

NUMBER OF RETAIL (BASE) RECORDS
AND MATCHES AGAINST DLA WHOLESALE RECORDS

Base	# retail records	Total # matched	%	# aircraft item matches	%
CONUS					
Langley	22,104	14,265	65	9,353	42
England	11,304	7,531	67	4,963	44
Little Rock	19,666	12,089	61	8,159	41
Minot	24,569	16,467	67	10,950	45
Randolph	12,798	8,615	67	6,022	47
OCONUS					
Bitburg	21,577	11,543	53	6,967	32
Bentwaters	22,974	14,663	64	9,517	41
Kunsan	20,895	11,050	53	6,091	29
Clark	47,217	25,012	53	14,622	31
Elmendorf	35,997	19,277	54	11,701	33

Table B-11 lists the data elements in the retail records from AFLMC that were used as input to the retail model.

Following Table B-11 is a program listing (Figure B-1) for the retail model used to analyze the retail data from the 10 representative bases. The model is designed to simultaneously compute expected retail backorders (due-outs) under baseline conditions and then with 5 days of delay added to OST with no increase in retail stockage levels.

The mathematics in the model is based on material in the January 1986 AFLMC publication, *Stockage Policy Course Material for Supply Officers*, by (then) Maj Douglas Blazer (USAF), Mr. Wayne Faulkner, and Capt Martha Ham (USAF). The relevant section is in Appendix D: "Air Force Consumable Stockage Policy – Depth," pages 42–47, where the SBSS method for computing stockage level requirements is described. The SBSS model is a one-item-at-a-time model rather than a *system* backorder-minimization model. (AFLMC and the Air Force are in the

TABLE B-11

RETAIL RECORD DATA ELEMENTS

NSN	National stock number
PRICE	Unit price
SOS	Routing Identifier (wholesale source of supply)
DOFD	Date of first demand
CRD	Cumulative recurring demands
CFACT	Standard deviation (C factor)
DMDLVL	Demand level [= economic order quantity (EOQ) + OST quantity (OSTQ) + safety level quantity (SLQ)]
BSTK	Bench stock flag
CDSQRD	Cumulative demand quantity squared

process of developing a system model for retail use; they refer to it as an "aggregate" model.)

The retail model assumes a Laplace distribution for demand in a leadtime (leadtime being an order and ship time in the retail case) as opposed to the normal distribution assumption used in the Air Force SBSS model. The Laplace distribution provides a reasonable approximation to the normal and is easier to program. In any case, the model was calibrated to compute EBOs consistent with real-world, outstanding unit backorders for DLA items at Air Force bases worldwide, as reported in the M32 "Due Out Schedule—Supplies" reports. The model was calibrated by multiplying the estimate of demand variance from the retail data (expressed in terms of a derived value for the standard deviation in demand in an OST) by an arbitrary "sigma adjustment factor" (SIGFAC in the program) equal to 0.5. (In effect, we followed SBSS procedures for computing the standard deviation in demand in an OST and then halved it.)

The model is programmed in the PARADOX Application Language (PAL), part of the personal computer (PC)-based PARADOX (Version 3.0) data base software package used in the analysis.

```
CLEARALL
; This script computes expected retail backorder
; quantities from data in any one of the 5 CONUS retail files.  The
; program DOESN'T add fields, so you can't see individual record results.
; High-priority due-outs obtained by multiplying TEBO values by (0.2);
; SMR data not used.
; Using AFLMC retail data from 9/30/88 (=8274).
; TO SEE HOW MANY ADDITIONAL LRU EBOS WE GET AT "base" WHEN DLA EBOS
; INCREASE 23.6%, AD S .236 X 21.2 = 5 DAYS TO OST AT "base" 15+5 = 20
; DAYS AND COMPUTES DELTA IN LRU EBOS

RELEASE VARS ALL
view "randolph"

TEBO = 0
TEBO2 = 0
TLRUBO = 0
TLRUBO2 = 0

@2,12
?? "ENTER SIGFAC:"
ACCEPT "N" TO SIGFAC
SCAN
  price=[PRICE]/100.0

; DDR ROUTINE

SWITCH
  case [DOFD]<7090: days = 545
  case [DOFD]<8000: days = 274 + (7365-[DOFD])
  otherwise:        days = max(180,8274-[DOFD])
ENDSWITCH

ddr = [CRD]/days

; ECONOMIC ORDER QUANTITY (Q) ROUTINE

Q =8.3*sqrt(ddr*365*price)/price

; PIPELINE (OSTQ) ROUTINE
;  (FOR CONUS, AVG OST = 15 DAYS and AVG VARIANCE IN OST = 50 DAYS)
; (based on data in A LMC OST report, Appendix B, for Little Rock,
Minot,England
;  DELTA BASED ON ADDING .236x21.2 =5 DAYS TO OSTs
  ostq = ddr*15
  ostq2 = ddr*20
```

FIG. B-1. RETAIL MODEL PAL CODE (CONUS VERSION)

```
; VARIANCE IN DEMAND AND LEADTIME ROUTINE
; (TO GET VARIANCE IN LEADTIME DEMAND)

vod = ([cdsqrd] - pow([crd],2)/days)/days

sigma = sigfac * sqrt(vod*15 + pow(ddr,2)*50)
sigma2= sigfac * sqrt(vod*20 + pow(ddr,2)*50)
; (variance of leadtime demand = sigma squared)

   slq = [cfact]*sigma

 IF [DMDLVL] = 0
    THEN
         EBO = ostq
         EBO2 = ostq2
    ELSE
        templ= MAX(-1.414*Q/sigma,-700)
        templl=MAX(-1.414*Q/sigma2,-700)
        temp2= MAX(-1.414*[cfact],-700)

        EBO = (.25*POW(sigma,2)/Q)*(1 - EXP(templ))*EXP(temp2)
       EBO2 = (.25*POW(sigma2,2)/Q)*(1 - EXP(templl))*EXP(temp2)
 ENDIF

;  ROUTINE TO ESTIMATE LRU EBOS
   SWITCH
      CASE ISBLANK([OCNT]): LRUBO=EBO/2
                            LRUBO2=EBO2/2
      CASE ([OCNT]+[FCNT])=0: LRUBO=EBO/2
                                    LRUBO2=EBO2/2
      OTHERWISE: LRUBO = EBO*([OCNT]/([OCNT]+[FCNT]))
                 LRUBO2 = EBO2*([OCNT]/([OCNT]+[FCNT]))

   ENDSWITCH

TEBO = TEBO + EBO
TEBO2 = TEBO2 + EBO2
TLRUBO = TLRUBO + LRUBO
TLRUBO2 = TLRUBO2 + LRUBO2

ENDSCAN

DELTA = 100*(TEBO2-TEBO)/TEBO

; ADJUST LRU EBO VALUES BY RATIO OF PR GP 1 & 2 TO PR GRP 1,2&3 (.2)
TLRUBO = .2 * TLRUBO
TLRUBO2 = .2 * TLRUBO2
DELTA2 = TLRUBO2  - TLRUBO
PCENT = 100*DELTA2/TLRUBO
```

FIG. B-1. RETAIL MODEL PAL CODE (CONUS VERSION) (Continued)

```
  TEBO=ROUND(TEBO,0)
  TEBO2=ROUND(TEBO2,0)
  DELTA=ROUND(DELTA,1)
  TLRUBO=ROUND(TLRUBO,0)
  DELTA2=ROUND(DELTA2,2)
  PCENT=ROUND(PCENT,1)

PRINTER ON
@1,10  ??"Baseline ebos                    =  ",STRVAL(  TEBO   ),"\n"
@3,10  ??"Ebos with increased depot delay  =  ",STRVAL(TEBO2),"\n\n"
@5,10  ??"Percent increase in ebos is      =  ",STRVAL(DELTA),"%\n\n"
@7,10  ??"Baseline LRU EBOs                =  ",STRVAL(TLRUBO),"\n"
@9,10  ??"Additional LRU EBOS generated    =  ",STRVAL(DELTA2),"\n"
@11,10 ??"Percent increase in LRU EBOs     =  ",STRVAL(PCENT),"%\n\n"

PRINTER OFF
DO_IT!
RELEASE VARS ALL
```

FIG. B-1. RETAIL MODEL PAL CODE (CONUS VERSION) (Continued)

The only difference in the OCONUS version of the model is the following code:

```
;  (FOR OCONUS, AVG OST = 60 DAYS and AVG VARIANCE IN OST = 500
;  DAYS) (based on data in AFLMC OST report, Appendix B, for Kunsan
;  and Upper Heyford) DELTA BASED ON ADDING .236x21.2 =5 DAYS TO
;  OSTs
   ostq = ddr*60
   ostq2 = ddr*65
```

THE WHOLESALE MODEL

Figure B-2 on the following pages presents the PAL code for the SAMMS-like wholesale model used to analyze how wholesale EBOs would change for the 176,246 demand-based WSSP/USAF items if DLA were to reduce every item's safety-level quantity by 20 percent. The model computes the EBOs for each item based on the safety-level quantity (an input data element) in the file for the item. It simultaneously computes the item's EBOs if the safety-level quantity is reduced by 20 percent.

The mathematics in the model follows the SAMMS safety-level methodology described in the August 1985 DLA publication, *Review of SAMMS Requirements Computations*, by Mary K. Cyrus, et. al., DLA Operations Research and Economic Analysis Office, Headquarters, Defense Logistics Agency, Cameron Station, Alexandria, Virginia.

```
CLEARALL
;  This script computes expected backorder quantities
;  from the wholesale DLA data for the 176,246 demand-based WSSP/USAF
items
RELEASE VARS ALL
view "smr"  (or "nosmr" depending on whether smr data available)

QFDCNT   =0
FBCNT    =0
ALPHACNT =0
ACNT     =0
MADLTCNT =0
SLCNT    =0

INV$      = 0
SL$       = 0
BKAMT     = 0
BKSLQ     = 0
BKSLQTOT  = 0
DEBO20    = 0

SCAN
    price=[price]/100
    alpha=[alpha]/100

    rpq=max([rpq],[owrmrp]+[slq])
    qfd1=91*(rpq-[owrmrp]-[slq])/([alt]+[plt])
    qfd2=[qfd]
    qfd = max(qfd1,qfd2)
      IF qfd<=0
         THEN QFDCNT=QFDCNT+1
            qfd=1
      ENDIF

    mondmd=qfd/3

      IF alpha<= 0
         THEN alpha=0.2 ALPHACNT =ALPHACNT+1
      ENDIF

    pcm = [pcm]
      IF pcm=0
         THEN pcm=1
      ENDIF

     Q   = pcm*mondmd
     Q   = ROUND(Q,0)
```

FIG. B-2. WHOLESALE MODEL

```
SWITCH
     CASE [fbc]=1: T=([alt]+[plt])/30
     CASE [fbc]=2: T=([alt]+[plt])/91
     OTHERWISE: FBCNT=FBCNT+1
              T=([alt]+[plt])/91
   ENDSWITCH

   SWITCH
     CASE  alpha <=.05 : MULT=.70+.36*T
     CASE  alpha <=.10 : MULT=.63+.41*T
     CASE  alpha <=.15 : MULT=.57+.46*T
     CASE  alpha <=.20 : MULT=.55+.49*T
     CASE  alpha <=.25 : MULT=.50+.53*T
     CASE  alpha <=.30 : MULT=.46+.56*T
     CASE  alpha <=.35 : MULT=.44+.58*T
     CASE  alpha <=.40 : MULT=.42+.60*T
     CASE  alpha <=.45 : MULT=.40+.62*T
     CASE  alpha <=.50 : MULT=.37+.64*T
     CASE  alpha <=.55 : MULT=.37+.65*T
     CASE  alpha <=.60 : MULT=.36+.66*T
     CASE  alpha <=.65 : MULT=.33+.68*T
     CASE  alpha <=.70 : MULT=.31+.69*T
     CASE  alpha <=.75 : MULT=.30+.70*T
     CASE  alpha <=.80 : MULT=.31+.70*T
     CASE  alpha <=.85 : MULT=.29+.71*T
     CASE  alpha <=.90 : MULT=.30+.71*T
     CASE  alpha <=.99 : MULT=.30+.71*T
     OTHERWISE: ACNT=ACNT+1
   ENDSWITCH

     madlt  = MULT *
    (alpha*(qfd - (([andp]/100)*[ndql]+[rdql])) + (1-alpha)*([madq]/10))

      IF  madlt <=0
         THEN MADLTCNT=MADLTCNT+1
               madlt =0
               bkslq =0
         ELSE
               k =[slq]/(1.25* madlt)
                 temp= k/(-0.7071)
                 IF ABS(temp)>700 THEN temp=-700 ENDIF
                 temp2=-1.13*Q/madlt
                 IF ABS(temp2)>700 THEN temp2=-700 ENDIF
                  bkslq = madlt * madlt * (1-
exp(temp2))*exp(temp)/(Q*2.56)
                  bkslq =ROUND(bkslq,2)
                  debo  = bkslq/exp(.2*temp)
      ENDIF
```

FIG. B-2. WHOLESALE MODEL (Continued)

```
            IF [slq]<=0
               THEN SLCNT=SLCNT+1
            ENDIF

       INV$ =  INV$ + ([rpq]*price)

       SL$ = SL$ + ([slq]*price)

       BKAMT=BKAMT + [bkqty]

       BKSLQTOT = BKSLQTOT + bkslq

       DEBO20    = DEBO20 + debo

ENDSCAN

       BKSLQTOT = ROUND(BKSLQTOT,0)
       DEBO20    = ROUND(DEBO20,0)

PRINTER ON

@1,10 ??"Computed QFD is 0    ",STRVAL(  QFDCNT   ),"  times\n"
@3,10 ??"FBC not = to 1 or 2  ",STRVAL(  FBCNT    ),"  times\n"
@5,10 ??"ALPHA changed to .2  ",STRVAL(  ALPHACNT ),"  times\n"
@7,10 ??"New ALPHA not in table range  ",STRVAL(  ACNT     ),"  times\n"
@9,10 ??"MADLT <= 0  ",STRVAL(  MADLTCNT ),"  times\n"
@11,10 ??"SLQ <= 0   ",STRVAL(  SLCNT    ),"  times\n\n"

@15,10 ??"Total rpq (inventory) value     =  $",STRVAL( INV$     ),"\n"
@17,10 ??"Total slq (safety level) value  =   $",STRVAL(  SL$
),"\n\n"
@19,10 ??"Observed backorders  =  ",STRVAL(  BKAMT    ),"\n"
@21,10 ??"EBO (bkslq) total    =  ",STRVAL(BKSLQTOT),"\n"
@23,10 ??"EBO (bkslq) with 20% reduction in SLQs  =  ",STRVAL(DEBO20),"\n"

PRINTER OFF

DO_IT!

RELEASE VARS ALL
```

FIG. B-2. WHOLESALE MODEL (Continued)

THE WHOLESALE "SYSTEM" MODEL FOR F-16 ITEMS

This model has two parts. The first part is identical to the previous wholesale model that calculates the EBOs for each item in turn on the basis of the item's SAMMS safety level. While doing that, however, it accumulates the information needed to define the Lagrange multiplier (LAMSUM) required to find the safety levels that minimize total backorders for the *collection* of items being processed. On a second pass through the collection, the model recomputes item safety levels, using the Lagrange multiplier *and* the constraints: no negative safety level, and safety level must be less than the smaller of leadtime demand and three standard deviations in leadtime demand. Figure B-3 contains the code for the model.

```
CLEARALL
;  This script computes expected backorder quantities
;  from data in "smr"and "nosmr" and computes SYSTEM
;  sl quantities to achieve same EBOs for F16 components
RELEASE VARS ALL
view "f16"

SYSSLQ      = 0
LAMSUM      = 0
SUMBK       = 0
BKSLQTOT    = 0
CONSYSL     = 0
ZEROSL      = 0
CHECKER     = 0

QFDCNT   =0
FBCNT    =0
ALPHACNT =0
ACNT     =0
MADLTCNT =0
SLCNT    =0
SLCNT2   =0
NEWKNT   =0

INV$     = 0
SL$      = 0
BKAMT    = 0
BKSLQ    = 0
DEBO20   = 0

SCAN
    price=[price]/100
    alpha=[alpha]/100
```

FIG. B-3. WHOLESALE SYSTEM MODEL FOR F-16 ITEMS

```
rpq=max([rpq],[owrmrp]+[slq])
qfd1=91*(rpq-[owrmrp]-[slq])/([alt]+[plt])
qfd2=[qfd]
qfd = max(qfd1,qfd2)
  IF qfd<=0
     THEN QFDCNT=QFDCNT+1
        qfd=1
  ENDIF

mondmd=qfd/3

  IF alpha<= 0
     THEN alpha=0.2 ALPHACNT =ALPHACNT+1
  ENDIF 2

 pcm = [pcm]
  IF pcm=0
     THEN pcm=1
  ENDIF

 Q   = pcm*mondmd
 Q   = ROUND(Q,1)

SWITCH
  CASE [fbc]=1: T=([alt]+[plt])/30
  CASE [fbc]=2: T=([alt]+[plt])/91
  OTHERWISE: FBCNT=FBCNT+1
             T=([alt]+[plt])/91
ENDSWITCH

SWITCH
  CASE  alpha <=.05 : MULT=.70+ 36*T
  CASE  alpha <=.10 : MULT=.63+.41*T
  CASE  alpha <=.15 : MULT=.57+.46*T
  CASE  alpha <=.20 : MULT=.55+.49*T
  CASE  alpha <=.25 : MULT=.50+.53*T
  CASE  alpha <=.30 : MULT=.46+.56*T
  CASE  alpha <=.35 : MULT=.44+.58*T
  CASE  alpha <=.40 : MULT=.42+.60*T
  CASE  alpha <=.45 : MULT=.40+.62*T
  CASE  alpha <=.50 : MULT=.37+.64*T
  CASE  alpha <=.55 : MULT=.37+.65*T
  CASE  alpha <=.60 : MULT=.36+.66*T
  CASE  alpha <=.65 : MULT=.33+.68*T
  CASE  alpha <=.70 : MULT=.31+.69*T
  CASE  alpha <=.75 : MULT=.30+.70*T
  CASE  alpha <=.80 : MULT=.31+.70*T
  CASE  alpha <=.85 : MULT=.29+.71*T
```

FIG. B-3. WHOLESALE SYSTEM MODEL FOR F-16 ITEMS (Continued)

```
     CASE  alpha <=.90 : MULT=.30+.71*T
     CASE  alpha <=.99 : MULT=.30+.71*T
     OTHERWISE: ACNT=ACNT+1
   ENDSWITCH

     madlt  = MULT *
    (alpha*(qfd - (([andp]/100)*[ndql]+[rdql])) + (1-alpha)*([madq]/10))

      IF  madlt <=0
         THEN MADLTCNT=MADLTCNT+1
               madlt =0
               bkslq =0

         ELSE
               k =[slq]/(1.25* madlt)
                 temp= k/(-0.7071)
                 IF ABS(temp)>700 THEN temp=-700 ENDIF
                 temp2=-1.13*Q/madlt
                 IF ABS(temp2)>700 THEN temp2=-700 ENDIF
                  bkslq = madlt * madlt * (1-exp(temp2))*exp(temp)/(Q*2.56)
                  bkslq =ROUND(bkslq,2)
                  debo  = bkslq/exp(.2*temp)
      ENDIF

      LAMSUM = LAMSUM + price*madlt

           IF [slq]<0
              THEN SLCNT=SLCNT+1
           ENDIF
           IF [slq]=0
              THEN SLCNT2 = SLCNT2+1
           ENDIF


      INV$ =  INV$ + ([rpq]*price)

      SL$ = SL$ + ([slq]*price)

      BKAMT=BKAMT + [bkqty]

      BKSLQTOT = BKSLQTOT + bkslq

      DEBO20    = DEBO20 + debo

ENDSCAN
PRINTER ON
@3,10 ??"LAMSUM  =    ",STRVAL( LAMSUM    ),"\n\n"
PRINTER OFF
```

FIG. B-3. WHOLESALE SYSTEM MODEL FOR F-16 ITEMS (Continued)

```
SCAN
    price=[price]/100
    alpha=[alpha]/100

    rpq=max([rpq],[owrmrp]+[slq])
    qfd1=91*(rpq-[owrmrp]-[slq])/([alt]+[plt])
    qfd2=[qfd]
    qfd = max(qfd1,qfd2)
      IF qfd<=0
         THEN
            qfd=1
      ENDIF

     mondmd=qfd/3

      IF alpha<= 0
         THEN alpha=0.2
      ENDIF

    pcm = [pcm]
      IF pcm=0
         THEN pcm=1
      ENDIF

     Q  = pcm*mondmd
     Q  = ROUND(Q,1)

   SWITCH
     CASE [fbc]=1: T=([alt]+[plt])/30
     CASE [fbc]=2: T=([alt]+[plt])/91
     OTHERWISE:
              T=([alt]+[plt])/91
   ENDSWITCH

   SWITCH
     CASE  alpha <=.05 : MULT=.70+.36*T
     CASE  alpha <=.10 : MULT=.63+.41*T
     CASE  alpha <=.15 : MULT=.57+.46*T
     CASE  alpha <=.20 : MULT=.55+.49*T
     CASE  alpha <=.25 : MULT=.50+.53*T
     CASE  alpha <=.30 : MULT=.46+.56*T
     CASE  alpha <=.35 : MULT=.44+.58*T
     CASE  alpha <=.40 : MULT=.42+.60*T
     CASE  alpha <=.45 : MULT=.40+.62*T
     CASE  alpha <=.50 : MULT=.37+.64*T
     CASE  alpha <=.55 : MULT=.37+.65*T
     CASE  alpha <=.60 : MULT=.36+.66*T
     CASE  alpha <=.65 : MULT=.33+.68*T
```

FIG. B-3. WHOLESALE SYSTEM MODEL FOR F-16 ITEMS (Continued)

```
  CASE  alpha <=.70 : MULT=.31+.69*T
  CASE  alpha <=.75 : MULT=.30+.70*T
  CASE  alpha <=.80 : MULT=.31+.70*T
  CASE  alpha <=.85 : MULT=.29+.71*T
  CASE  alpha <=.90 : MULT=.30+.71*T
  CASE  alpha <=.99 : MULT=.30+.71*T
  OTHERWISE: ACNT = ACNT

ENDSWITCH

  madlt  = MULT *
 (alpha*(qfd - (([andp]/100)*[ndql]+[rdql])) + (1-alpha)*([madq]/10))


 IF madlt >0
    THEN
      numer = 2.56 * Q * price * BKSLQTOT
      ARG = -1.13*Q/madlt
      IF ABS(arg)>700 THEN ARG=-700 ENDIF
      denom = madlt * LAMSUM * (1 - exp(ARG))
      newk  = -0.7071 * LN(numer/denom)
      newslq = 1.25 * newk * madlt * price
    ELSE
      newslq = [slq] * price
 ENDIF
      IF NEWK<0 THEN NEWKNT = NEWKNT + 1 ENDIF
      SYSSLQ = SYSSLQ + newslq

 IF madlt<=0
    THEN back = 0
    ELSE
         T1 = newk/-0.7071
         If abs(T1)>700 then T1=-700 endif
         T2 = -1.13*Q/madlt
         If abs(T2)>700 then T2=-700 endif
         back = madlt*madlt*(1-exp(T2))*exp(T1)/(Q*2.56)
    ENDIF

 CHECKER = CHECKER + back

 IF madlt > 0
    THEN
        slim = min(3.75*madlt,qfd*([alt]+[plt])/91)
              IF newk >= 0
                 THEN consl = min(1.25*newk*madlt,slim)
                 ELSE consl = 0
                      ZEROSL = ZEROSL + 1
              ENDIF
```

FIG. B-3. WHOLESALE SYSTEM MODEL FOR F-16 ITEMS (Continued)

```
            nunewk = consl/(1.25*madlt)
              temp = nunewk/-0.7071
            IF ABS(temp)>700 THEN temp = -700 ENDIF
             temp2 = -1.13*Q/madlt
            IF ABS(temp2)>700 THEN temp2=-700 ENDIF
                bk = madlt * madlt *(1 - exp(temp2))*exp(temp)/(Q*2.56)
        ELSE
                bk = 0
             consl = [slq]
     ENDIF

         SUMBK = SUMBK + bk
         CONSYSL = CONSYSL + consl*price


ENDSCAN

       BKSLQTOT = ROUND(BKSLQTOT,0)
       DEBO20   = ROUND(DEBO20,0)

       SYSSLQ   = ROUND(SYSSLQ,2)

       CONSYSL  = ROUND(CONSYSL,2)
         SUMBK  = ROUND(SUMBK,0)
       CHECKER  = ROUND(CHECKER,0)

PRINTER ON
@1,10 ??"      F-16 Results                    ","\n"
@2,10 ??"EBOs with constrained SLs are     =    ",STRVAL(SUMBK),"\n\n"
@3,10 ??"System SL $ with constraints      =   $",STRVAL(CONSYSL),"\n\n"
@4,10 ??"K was reset from neg to 0  ",STRVAL(ZEROSL),"  times\n\n\n"

@5,10 ??"   No constraints gives ",STRVAL(CHECKER)," ebos\n"
@6,10 ??"   versus input beta of ",STRVAL(BKSLQTOT)," ebos\n"
@7,10 ??"   System SL $ for same system EBOs  =   $",STRVAL(SYSSLQ),"\n"
@8,10 ??"   K factor is negative   ",STRVAL(NEWKNT),"times\n\n\n"

@9,10 ??"Computed QFD is 0    ",STRVAL(  QFDCNT   ),"  times\n"
@10,10 ??"FBC not = to 1 or 2  ",STRVAL(  FBCNT    ),"  times\n"
@11,10 ??"ALPHA changed to .2  ",STRVAL(  ALPHACNT ),"  times\n"
@12,10 ??"New ALPHA not in table range  ",STRVAL(  ACNT    ),"  times\n"
@13,10 ??"MADLT <= 0  ",STRVAL(  MADLTCNT ),"  times\n"
@14,10 ??"SLQ < 0   ",STRVAL(  SLCNT    ),"  times\n"
@15,10 ??"SLQ = 0   ",STRVAL(SLCNT2),"  times\n\n"

@16,10 ??"Total rpq (inventory) value     =  $",STRVAL( INV$     ),"\n"
@17,10 ??"Total slq (safety level) value  =   $",STRVAL(  SL$     ),"\n\n"
@18,10 ??"Observed backorders  =  ",STRVAL(  BKAMT    ),"\n"
@19,10 ??"EBO (bkslq) total    =  ",STRVAL(BKSLQTOT),"\n"
```

FIG. B-3. WHOLESALE SYSTEM MODEL FOR F-16 ITEMS (Continued)

```
@20,10 ??"EBO (bkslq) with 20% reduction in SLQs  =
",STRVAL(DEBO20),"\n\n"

PRINTER OFF
DO_IT!

RELEASE VARS ALL
```

FIG. B-3. WHOLESALE SYSTEM MODEL FOR F-16 ITEMS (Continued)

"MICAP" CAUSE CODES AND THE ROLE OF CONSUMABLES

We have not yet discussed a particular set of reports that, because they tend to get looked at more frequently, have probably had the greatest influence on the "conventional wisdom" about consumables. Those reports are "MICAP Cause Code Analysis Reports," which have contributed to the general view that in thinking about how supply performance affects readiness, we have to think just as much about consumables as we do about reparables. This view is reflected in many secondary-item-weapon-system-management (SIWSM) concept papers and implementation plans, which do not attempt to draw any significant distinction between how consumables should be treated in comparison with reparables.

Part of the underlying theme of this study is to suggest that, at least at the wholesale level, SIWSM for consumables does not need to be as detailed or elaborate a process as it can (and generally should) be for reparables. This analysis has sized how wholesale consumable supply performance affects readiness. The size of those effects is such that it may not be worthwhile to try to do more – i.e., build the enormously large inventory models and application files required to simultaneously handle consumables and reparables. (Some envision precisely that happening as a "necessary" part of the move to SIWSM.) Without trying to settle this debate, but only inform it, we take a second look at what the MICAP Cause Code Analysis Reports really tell us.

Table B-12 reproduces a MICAP Cause Code Analysis Report that was part of the worldwide M32 Supply Management Report for March 1989. A MICAP incident at a base occurs when base supply is unable to fill a demand related to not mission capable (NMC) or partially mission capable (PMC) end item, and a high-priority

requisition has gone off the base to obtain the required item from a wholesale supplier. (The term MICAP is a shortened form of "mission capable." It refers to a situation in which supply is *preventing* an end item from being fully mission capable.) The MICAP Cause Code Analysis Report reproduced in Table B-12 is typical, both in the number of MICAP incidents it describes, and in the relative frequencies of the different causes that it lists.

The first thing one notices – in the upper section of the report – is that consumable (EOQ) items account for the largest number of MICAP incidents at bases (22,128) and therefore the majority of high-priority MICAP requisitions that arrive at wholesale supply. EOQ items include both DLA items and AFLC-managed SSD items, but are all consumables. (To see how many of the EOQ incidents are for DLA items, we can look at the lower section in the "DLA" column, which, if we subtract it from the upper EOQ column, raises some interesting questions about how the SSD is doing.) But let's go further.

First, these are MICAP *incidents*. Nothing in this report tells us how long the EOQ MICAPs last on average or whether they last longer than the MICAPs for reparables. [That kind of information is captured in the Due-Out Schedule – Supplies reports, which is what we used to compare the relative roles of AFLC and DLA items in the pie chart (Figure 1-1) in Chapter 1 of the main text.]

Second, we need to remember that an end item does not need to be "grounded" (i.e., rendered totally NMC) in order that an incident qualify as a MICAP incident. Partially mission capable (PMC) end items also justify a MICAP requisition, according to the rules. But PMC means only that the end item is not capable of performing "all" its assigned missions. That means if any of its subsystems are degraded in any way (e.g., a knob is broken), the PMC classification can be justified. That makes it easier to "MICAP" a requisition, which increases the chances of getting the wholesale inventory control point (ICP) to pay attention. If MICAPs really corresponded to disabled end items, the numbers in monthly MICAP reports (45,591 incidents in March 1989, for example) would make one wonder how it is possible that any of the 9,100 aircraft in the Air Force are ever able to fly.

Next, within EOQ incidents alone, it is enough to focus on the cause codes "A", "B", "H", "J", and "K", which consistently account for more than 90 percent of the total EOQ MICAP incidents each month. If we do that, some interesting conclusions

TABLE B-12

MICAP CAUSE CODE ANALYSIS REPORT

CAUSE CODE	REP CYCLE XD		REP CYCLE XF		EOQ ITEMS		EQMT ITEMS		TOTAL	
	NUMBER	PCT	NUMBER	PCT	NUMBER	PCT	NUMBER	PCT	NUMBER	PCT
A – NO STK LVL-NO DEMAND	3016	14	1177	39	11177	50	17	100	15387	33
B – NO STK LVL-W/DEMANDS	1833	8	425	14	2553	11	0	0	4811	10
C – IM/SM PROHIBITS LVL	1	0	2	0	12	0	0	0	15	0
D – BASE DECISION-NO LVL	0	0	1	0	135	0	0	0	136	0
F – FULL STOCK-0 BALANCE	68	0	22	0	109	0	0	0	199	0
G – FULL STOCK-ASSETS AWP	701	3	48	1	15	0	0	0	764	1
H – <FULL STK-RQN > STD	11456	55	642	21	3870	17	0	0	15968	35
J – <FULL STK-RQN < STD	784	3	263	8	2601	11	0	0	3648	8
K – FULL STK-NO DUE IN	1006	4	231	7	1618	7	0	0	2855	6
P – COMMAND UNIQUE	0	0	0	0	0	0	0	0	0	0
R – FULL STK-INACCESSIBLE	1054	5	111	3	15	0	0	0	1180	2
S – <FULL STK (G/H)	341	1	9	0	5	0	0	0	355	0
T – <FULL STK (G/J)	20	0	5	0	0	0	0	0	25	0
X – <FULL STK (G/K)	63	0	2	0	0	0	0	0	65	0
Z – INITIAL SHORTAGE	126	0	39	1	18	0	0	0	183	0
TOTAL	20469		2977		22128		17		45591	

CAUSE CODE	5 ALCs[a]		DLA		OTHER		TOTAL	
	NUMBER	PCT	NUMBER	PCT	NUMBER	PCT	NUMBER	PCT
A – NO STK LVL-NO DEMAND	5350	22	5611	57	4426	38	15387	33
B – NO STK LVL-W/DEMANDS	2238	9	1159	11	1414	12	4811	10
C – IM/SM PROHIBITS LVL	1	0	0	0	14	0	15	0
D – BASE DECISION-NO LVL	15	0	13	0	108	0	136	0
F – FULL STOCK-0 BALANCE	103	0	52	0	44	0	199	0
G – FULL STOCK-ASSETS AWP	606	2	7	0	151	1	764	1
H – <FULL STK-RQN > STD	11911	49	1160	11	2897	25	15968	35
J – <FULL STK-RQN < STD	1436	6	58	10	1171	10	3648	8
K – FULL STK-NO DUE IN	1335	5	732	7	788	6	2855	6
P – COMMAND UNIQUE	0	0	0	0	0	0	0	0
R – FULL STK-INACCESSIBLE	920	4	20	0	240	2	1180	2
S – <FULL STK (G/H)	306	1	0	0	49	0	355	0
T – <FULL STK (G/J)	18	0	2	0	5	0	25	0
X – <FULL STK (G/K)	52	0	0	0	13	0	65	0
Z – INITIAL SHORTAGE	139	0	14	0	30	0	183	0
TOTAL	24430		9811		11350		45591	

[a] Five AFLC Air Logistics Centers (combined): Oklahoma City ALC, Warner-Robins ALC, San Antonio ALC, Sacramento ALC, and Ogden ALC.

emerge about the relative importance of *wholesale* consumables management policy as compared to *retail* consumables management policy.

Cause Code "A" describes what is consistently the single largest cause of EOQ MICAPs at bases: Base supply does not stock the item because there has been no previous demand. *All* of these Cause Code "A" MICAPs will continue to occur, of course, independent of any action wholesale managers take. Wholesalers might be able to reduce wholesale delay for such items by raising wholesale levels (assuming they could identify the items in advance), but even then Cause Code "A" MICAPs would continue to persist as outstanding due-outs for a time at least equal to an OST. There is essentially nothing wholesale managers can do to alleviate the problem of Cause Code "A" MICAPs.

Like Cause Code "A", Cause Codes "B", "J", and "K" MICAPs reflect problems at the *retail* level, that wholesale supply managers can do nothing about. Cause Code "B" means that there may be something wrong with retail "range" decisions: How much demand must occur before we authorize retail stockage? Nothing that wholesale managers do influences that decision.

Cause Code "J" means base supply has less than full stockage, but that the requisition from wholesale is still within the Uniform Materiel Movement and Issue Priority System (UMMIPS) time standard for delivery. MICAPs in this category suggest that base stockage is not high enough to cover even normal replenishment time. That is, again, a retail stockage problem, which wholesale managers can do nothing about (unless they assume control of retail stockage policy). [AFLMC suggests that one of the reasons some bases do not always carry the full replenishment pipeline is that bench stock levels may be generous, and not stocking the full pipeline frees operation and maintenance (O&M) dollars for other uses.]

Cause Code "K" MICAPs suggest either a problem with base ordering procedures, or more likely, a shortage of O&M funds to order replenishment stocks from DLA Cause Code "K" says that the base has less than full stockage but has not ordered replenishment (there is no due-in). Again, this is a retail problem that wholesale managers can do nothing about.

Among the prime cause codes, Cause Code "H" is the only one that wholesale managers may be able to do something about. Cause Code "H" says that a MICAP due-out occurred because wholesale replenishment is taking longer than the

UMMIPS standard says it should. One reason that happens is if wholesale supply delays are longer than they should be, because wholesale stockage is too low. Even here, we have to qualify when looking just at DLA items. From the "DLA" column in the bottom section of the report, we see that DLA items account for only 1,160 (30 percent) of the 3,870 Cause Code "H" EOQ MICAPs. With 140 major installations in the Air Force, 1,160 DLA MICAPs represent an average of only 8 MICAPs for DLA items per base per month. SSD items account for twice as many Cause Code "H" EOQ MICAPs (2,710 = 3,870 – 1,160), and repair cycle (ERRC Code XD) items account for almost three times as many Cause Code "H" MICAPs (11,456) as *all* EOQ items combined.

The lesson from this is that although wholesale consumables managers can do some things to positively influence readiness, they are not driving the train. Retail supply policy in general, and wholesale supply policy for reparables in particular, are more than equal partners when it comes to affecting readiness.

APPENDIX C

GLOSSARY

AA	=	aircraft availability
AAC	=	Alaskan Air Command
AAM	=	Aircraft Availability Model
AFB	=	Air Force Base
AFLC	=	Air Force Logistics Command
AFLMC	=	Air Force Logistics Management Center
AFRES	=	Air Force Reserves
ALC	=	Air Logistics Center
ALT	=	administrative leadtime
ANG	=	Air National Guard
ARS	=	average requisition size
ASD(P&L)	=	Assistant Secretary of Defense (Production and Logistics)
AWP	=	awaiting parts
BAI	=	backup aircraft inventory
BRT	=	base repair time
BW	=	Bomb Wing
CONUS	=	contiguous 48 states
CRD	=	cumulative recurring demands
D033	=	ALC Middle Management Reports
D041	=	Recoverable Consumption Item Requirements System
D049	=	Master Material Support Record
DCSC	=	Defense Construction Supply Center

DDR	=	daily demand rate
DESC	=	Defense Electronics Supply Center
DGSC	=	Defense General Supply Center
DIDB	=	DLA Item Data Bank
DIDS	=	Defense Integrated Data System
DISC	=	Defense Industrial Supply Center
DLA	=	Defense Logistics Agency
DLAM	=	DLA Manual
DLR	=	depot-level reparable
DLSC	=	Defense Logistics Service Center
DMIF	=	Depot Maintenance Industrial Fund
DMR	=	Defense Management Review
DoD	=	Department of Defense
DoDD	=	DoD Directive
DoDI	=	DoD Instruction
DOFD	=	date of first demand
DORO	=	DLA Operations Research Office
DPSC	=	Defense Personnel Support Center
DRT	=	depot repair time
DWSSO	=	DLA Weapon System Support Office
EBO	=	expected backorder
EOQ	=	economic order quantity
ERRC	=	expendability, recoverability, repairability category
FMC	=	fully mission capable
FSC	=	Federal Supply Class
FSG	=	Federal Supply Group
FTW	=	Flying Training Wing

GSA	=	General Services Administration
GSD	=	General Support Division
HQ	=	Headquarters
IAQ	=	issuable asset quantity
ICC	=	item category code
ICP	=	inventory control point
LMI	=	Logistics Management Institute
LP	=	local purchase
LRU	=	line replaceable unit
LSAR	=	Logistics Support Analysis Record
MAC	=	Military Airlift Command
MADLT	=	mean absolute deviation in leadtime
MC	=	mission capable
MICAP	=	mission capability
MILSTD	=	Military Standard
MILSTEP	=	Military Supply and Transportation Evaluation Procedures
MPC	=	maintenance priority code
NFR	=	nonfill rate
NMC	=	not mission capable
NMCB	=	not mission capable–both
NMCS	=	not mission capable–supply
NRTS	=	not reparable this station
NSN	=	national stock number
NSO	=	numeric stockage objective
O&M	=	operation and maintenance
OCONUS	=	outside contiguous 48 states
OST	=	order-and-shipping time

OWRMRP	=	other war reserve materiel requirements – protectable
PAI	=	primary aircraft inventory
PAL	=	PARADOX Application Language
PCM	=	procurement cycle months
PLT	=	procurement leadtime
PMC	=	partially mission capable
PMCB	=	partially mission capable–both
PMCS	=	partially mission capable–supply
PNP	=	"percent needing parts"
POS	=	peacetime operating stock
Q	=	order quantity
QFD	=	quarterly forecasted demand
RDB	=	Requirements Data Bank
RO	=	requisitioning objective
ROP	=	reorder point
RPQ	=	reorder point quantity
SAMMS	=	Standard Automated Materiel Management System
SBSS	=	Standard Base Supply System
SIWSM	=	secondary item weapon system management
SLQ	=	safety-level quantity
SMPG	=	Supply Management Policy Group
SMR	=	source, maintenance, and recoverability
SOS	=	source of supply
SRU	=	shop replaceable unit
SSC	=	Standard Systems Center
SSC	=	Supply Status Code
SSD	=	Systems Support Division

SSR	=	supply support request
TAC	=	Tactical Air Command
TAW	=	Tactical Airlift Wing
TFW	=	Tactical Fighter Wing
UMMIPS	=	Uniform Materiel Movement and Issue Priority System
USAF	=	U.S. Air Force
VSL	=	variable safety level
WOW	=	weight-on-wheels
WRSK	=	War Readiness Spares Kit
WSIC	=	weapon system indicator code
WSSP	=	Weapon System Support Program

Definitions:

"Point-of-use demand" refers to demands made by maintenance personnel on retail supply points. Point-of-use demand in the Air Force can be classified as being generated by aircraft or non-aircraft systems. If maintenance demands on retail supply are only to fill bench stock, point-of-use demand refers to maintenance demand on bench stock.

"Demand-by-weapon-system information" refers to demand data stratified by weapon system: this percentage of total point-of-use demand is attributable to this weapon system; this percentage to that weapon system; and so forth.